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THE GOLD REGIONS OF THE STRAIT OF MAGELLAN AND TIERRA DEL FUEGO

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LOCATION OF THE REGION[1]

The Strait of Magellan intersects the southern end of South America from east to west. To the north of the strait is Patagonia, to the south of it is the archipelago of Tierra del Fuego. Both these regions are owned partly by Chile and partly by the Argentine Republic. The dividing line follows the Andes southward in Patagonia to the Strait of Magellan, thence eastward for some distance along the strait, and thence southward again through Tierra del Fuego, giving most of that archipelago to Chile, but an important part on the eastern side to Argentine. The Chilean possessions in the Magellan region, on both sides of the strait, are officially known as the Territory of Magallanes, a term locally abbreviated to simply "Magallanes."

Patagonia represents the southern end of the mainland of South America, terminating at Cape Froward, in the Strait of Magellan. The name Tierra del Fuego properly belongs to the whole archipelago of islands lying south of the Strait of Magellan and north of Cape Horn, though sometimes it is applied to the one large island which comprises most of the land area of the group and which is often

[1] During the year 1907 the writer twice visited the Strait of Magellan and had an opportunity to learn something of the gold-mining industry of that region. Other researches in South America prevented his making a special study of the deposits on which this industry has been built up, but it is hoped that the following general account of the occurrence and environment of the gold in this little-known region may be of some interest.

locally known as "the island," in distinction from the others. In the present paper the name Tierra del Fuego will be used to indicate the whole archipelago, and, as thus defined, it consists of one large island and many smaller ones. It comprises an area extending about 500 miles in a direction from northwest to southeast and about 200 miles in a direction from northeast to southwest, and from about 52° 30′ to almost 56° south latitude. The two main tidewater channels are the Strait of Magellan on the north and Beagle Channel near the southern part, intersecting the region from east to west. Between these two, and also south of Beagle Channel, are numerous other minor and transverse channels, dividing the archipelago into the many islands of which it is composed. (See map.)

GEOLOGY AND TOPOGRAPHY OF THE REGION

The western part of Patagonia is comprised in the main range of the Andes, dropping off abruptly on the Pacific side, while the eastern part is comprised in the low rolling country known as the pampas, sloping gradually to the Atlantic. South of the Strait of Magellan, in Tierra del Fuego, the western and southern parts of the archipelago are rugged and mountainous, some of the peaks rising from about 3,000 to about 7,000 feet above the sea. (See Fig. 2.) This region represents the southern extension of the Andes, which here turn from their usual north-and-south course to a northwest-and-southeast course, and then to an east-and-west course, finally terminating in the rugged Staten Island, the most easterly member of the archipelago. The northeastern part of the main island of Tierra del Fuego, however, is a more or less flat or rolling country, and partakes of the nature of the pampas of eastern Patagonia. In fact, just as the mountainous districts of Tierra del Fuego are the southerly extension of the Andes, so this part of the main island is geologically the southern extension of the pampas.

Tierra del Fuego probably owes its condition as a group of islands, instead of as a continuous land area, to a partial submergence of the southern end of South America. The numerous small but high and mountainous islands dropping off precipitously into the sea, following each other in quick succession along certain directions and separated by deep but narrow tidewater channels, strongly suggest what the

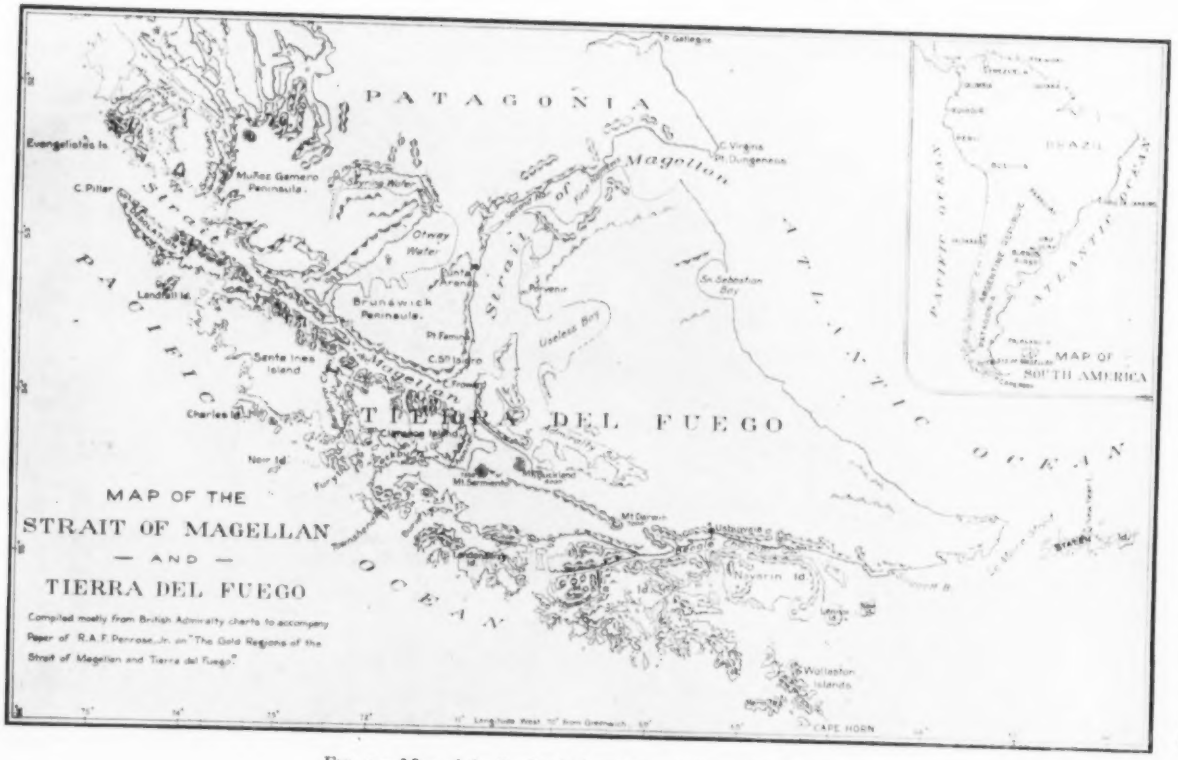

FIG. 1.—Map of the Strait of Magellan and Tierra del Fuego.

higher Andes range to the north would look like if it were submerged sufficiently to permit the sea to invade its lower parts. The islands appear to be the upper parts of old mountain peaks, and the numerous straits, channels, and bays, with their great depth and precipitous sides, appear to mark the courses of the old canyons and valleys now submerged. Whether the submergence is now at the maximum depth to which it has ever reached, or whether there has been some uplifting since the period of maximum submergence, is a question which cannot be fully discussed within the limits of the present article.

The rocks of southern Patagonia and Tierra del Fuego have not been much studied, but from the little that is known of them, it may be said that in the mountainous areas they are much like those of other parts of the southern Andes, granites, various igneous rocks, and slates being common; while in the low pampas country in eastern Patagonia and the northeast part of the main island of Tierra del Fuego, more or less soft, sandy and argillaceous strata predominate, probably belonging mostly to the Mesozoic and Cenozoic eras. Not only in its geology but in other respects, a large part of southern Patagonia and Tierra del Fuego is a little-known country. Various expeditions, especially those of the British ships the Adventure and the Beagle, have prepared good charts of the strait and neighboring waters, with accurate measurements of the depth of water and other nautical data most valuable to the navigator. These observations have been supplemented by later Chilean, American, French, and other expeditions. The outlines of most of the land-areas have also been fairly accurately mapped, and some of the mountains have been plotted and measured, but there are vast areas of country almost unknown beyond their shore lines. The advent of the sheep-raiser and the miner are rapidly giving us knowledge of some of these regions, but such information, though better than nothing, is necessarily vague.

DISCOVERY AND DISTRIBUTION OF THE GOLD DEPOSITS

Gold is said to have been discovered in southern Patagonia by the Chileans over forty years ago, and is supposed to have been known to the native Indians at a much earlier date, but it has been

produced in quantities sufficient to attract general attention only in the last twenty to twenty-five years. The gold in the gravels of Rio de las Minas, near Punta Arenas, was one of the earliest discoveries, and a number of miners soon began to work there. Another early discovery was the gold in the beach sands near Cape Virgins, at the eastern entrance of the Strait of Magellan, which was first discovered about 1876, but not actively worked until 1884. Then considerable excitement followed and prospecting parties overran a large part of southern Patagonia and Tierra del Fuego. An Austrian named Mr. Julius Popper was among the most active operators at that time, especially on the east coast of the main island of Tierra del Fuego. The search continued for several years with more or less activity,

FIG. 2.—A view in the Strait of Magellan.

sometimes the excitement subsiding, and sometimes breaking forth again when an especially rich discovery was made.

During this time, gold was found and actively worked in many places on both sides of the Strait of Magellan, but the principal localities were the following: the gravels in the Rio de las Minas near Punta Arenas; the beaches at Cape Virgins and from there southwestward along the shore to Point Dungeness; the gravels on several small streams to the eastward of where Porvenir now stands, across the strait from Punta Arenas; the beach at Paramo northeast of San Sebastian Bay, on the east coast of the main island of Tierra del Fuego; Navarin Island, Lennox Island, New Island, and Sloggett Bay in the extreme southern part of the archipelago near Cape Horn; New Year Island which lies north of Staten Island, at the eastern end of the archipelago; and several localities in the western islands of the archipelago. In fact, gold has been found to be very generally distributed almost all through the Magellan region, though

only in certain localities has it been profitably worked. Most of the important localities yet discovered are in the archipelago of Tierra del Fuego, though a few, such as on the beaches at Cape Virgins and Point Dungeness, are in Patagonia, on the north shore of the Strait of Magellan; and gold is also found in places along the southern coast of Chile, for some distance north of the Strait of Magellan.

About the year 1904 the preparations to use steam dredges in handling the gold-bearing gravel started afresh the boom that had

FIG. 3.—The town of Porvenir, Tierra del Fuego.

for a time been more or less quiescent. The old method of working the mines had been by hand, gathering the gold in pans, sluice-boxes, or other similar appliances. With the introduction of steam dredges, however, it became possible to handle the gravel much more cheaply and in much larger quantities. From all over Chile and Argentine again came the gold-seekers, with some from a still greater distance, and the usually almost deserted Strait of Magellan became animated with small craft. Since that time, though the excitement has subsided, work on the gold deposits has steadily progressed, and in a much more systematic manner than formerly. There were in

1907 some twelve or thirteen dredges in operation or being constructed, and the gold industry of the region promises soon to become a far more important business than in the days of handwork. The most active man in introducing the dredges has been an American, Mr. John D. Roberts, who for some years has been engaged in developing the gold industry of this region. The dredges are not used in handling the beach deposits, as the fury of the storms would soon batter them to pieces, and their use has so far been confined to the inland deposits.

FIG. 4.—The town of Punta Arenas, Strait of Magellan.

Until recently the largest gold-mining operations were at Paramo and Lennox Island, but since the introduction of the dredges, the most active operations are on the northwestern part of the main island of Tierra del Fuego, just across the strait from Punta Arenas. Here the town of Porvenir is the headquarters of the industry. This town has been a small settlement for some years, but it jumped into prominence in the gold boom of 1904, and is now a prosperous mining center of about 800 people. (See Fig. 3.) The mines are mostly some miles, and often many miles, from Porvenir, but the town is the supply point and the port at which the boats of the miners land.

In addition to the Porvenir region, mining on a smaller scale, but of more or less importance, is still going on at some of the other localities already mentioned.

The chief center of civilization in the whole region is the Chilean town of Punta Arenas, a name which in English means Sandy Point, and which refers to the spit of sandy land on which it is built. The town is on the Patagonian side of the Strait of Magellan and has a fairly good harbor. It is the seat of government in this part of the

FIG. 5.—Gold-bearing alluvium on the Rio del Oro, Tierra del Fuego.

Chilean possessions and is a very active place of some 12,000 people. (See Fig. 4.) It is the only large town in the Magellan region. The settlement of Ushuwaia, which is the seat of government of the Argentine part of Tierra del Fuego, is only a very small place, while several small mining or fishing camps, of which Porvenir is the largest, together with a few missionary posts, none of them containing more than a few persons, complete the list of settlements in this region. Punta Arenas is in 53° 9′ 42″ south latitude, and has the distinction of being the most southerly town of any considerable size in the southern hemisphere. Some of the places mentioned above are still

further south, and Ushuwaia is in almost 55° south latitude, but they are all very small settlements.

Punta Arenas was started by the Chilean government as a penal colony in 1843, but its location at that time was somewhat further south than at present. A few years later, in 1849, the settlement was moved to where it now stands. In the early days of Punta Arenas it was the scene of much disturbance, and on more than one occasion frightful bloodshed and massacre on the part of the convicts have

FIG. 6.—Gold-bearing alluvium on the Rio Pararich, Tierra del Fuego.

blackened its history. The Chilean government finally ceased using it as a penal colony and encouraged its settlement by free Chileans. For a long time it was the headquarters for sealing and whaling vessels, until the seals and whales became so nearly exterminated that the industry began to wane. It was also the wrecking headquarters for the Magellan region, and the many ships that were in distress or were dashed to pieces in the storms of this inhospitable region received the attention of the Punta Arenas wreckers.

In recent years, however, Punta Arenas has prospered greatly along other lines, first by the development of the sheep industry in Patagonia

and later by the advent of the gold miner. Its population is of a most cosmopolitan character, comprising, besides the native Chileans, many Austrians and a considerable number of Argentines, Germans, and English, as well as some Americans, French, and others. Punta Arenas bears much the same relation to the Far South as Dawson City, on the Yukon River, does to the Far North, both being isolated settlements on the borders of opposite polar regions, where, for vast distances, there is no other civilization; and though they are not

FIG. 7.—Gold-bearing alluvium on the Rio Verde, Tierra del Fuego.

large cities, their very isolation gives them a metropolitan air, for they are dependent on themselves for protection, amusement, and the general facilities of civilization. The one is the Antarctic metropolis and the other the Arctic metropolis of the Western Hemisphere; beyond both, civilization ceases.

MODE OF OCCURRENCE OF THE GOLD DEPOSITS

The gold of the Magellan region, including the Strait of Magellan and Tierra del Fuego, is, so far as at present known, most all in alluvial, or placer, deposits. Very few gold-bearing veins have been

found, though it may be said that, in a region so difficult as this is to prospect, gold-bearing veins might readily be overlooked. The alluvial deposits may be divided into two classes, those in beds of creeks or on hillsides, and those on sea beaches where they are subject to the action of the sea during rising and falling tides and during storms.

The alluvial deposits in beds of streams or on hillsides vary in gold contents from a few cents to a dollar or more per cubic yard,

FIG. 8.—Gold-bearing alluvium on the Rio Verde, Tierra del Fuego.

and sometimes, though less commonly, are considerably richer, but most of the ground that is now worked is said to range from twenty-five cents to fifty cents per yard. Under the conditions existing in the region, it is difficult to make very low grade ground pay, but some of the operators expect eventually, with steam dredges, to make a profit on very considerably lower-grade ground than they are working now. The gold-bearing beds vary from a few feet to many feet in thickness, ten to thirty feet or more being not uncommon. (See Figs. 5, 6, 7, 8, and 9.) An "overburden," or capping of barren ground, of variable thickness often occurs.

The gold on the beaches is sometimes on the immediate surface and sometimes covered by from a few inches to several feet of barren sand. On some beaches it is well up on the shore, on others it is near the water level and on still others it is below the water level. The sandy strata carrying the gold are rarely over a few inches in thickness, but often very rich. The gold is associated with large quantities of black sand, which seems to be mostly magnetite, and numerous small garnets.

FIG. 9.—Gold-bearing alluvium on the Rio Santa Maria, Tierra del Fuego.

The gold, whether from the creeks, hillsides, or beaches, is said to be quite pure, though it contains often a little copper and silver. It occurs generally in rather fine particles, but sometimes small nuggets, often flat and about the size of lima beans, occur, and occasionally still larger ones are found, but no very great nuggets have yet been discovered. The rarer minerals which occur in some other gold districts, like diamond, sapphire, topaz, etc., are said not to be found in this region, though a closer study of the deposits might reveal the presence of some of them.

As regards the origin of the gold deposits of the Magellan region,

it may be said that the alluvial deposits in the creeks and on the hillsides have doubtless been derived from the erosion of gold-bearing rocks, and though such rocks have not yet been found to any great extent in the region, they nevertheless probably exist and may sometime be discovered. If the Magellan region represents the partly submerged southern end of the continent, as already mentioned in this paper, many of these deposits may have been originally formed as ordinary alluvial deposits high up in the mountains, and brought down during the sinking era to a much lower level, while some of them may have been completely submerged in the sea. The gold in the beaches probably came largely from the later erosion of the alluvium in the creek beds and on the hillsides, and perhaps partly from old submerged alluvium from which the gold was thrown up by the sea. In either case the gold has been further concentrated by being washed over and over again on the beaches. It is said that the beaches, after having been carefully worked for gold, seem again to become rich in that metal after a storm or an unusually high tide.[1] This phenomenon is probably due partly to the action of the waves and currents in concentrating the gold which the imperfect methods of the miners have left behind in the sand, and partly to the washing up of fresh gold-bearing sand from depths that are undisturbed in ordinary weather or by ordinary tides. So well recognized is this enriching of the beaches, that the miners, after working all the sand that can be profitably handled, wait for the next storm or very high tide to come, and then wash the same spots over again with a good profit.

The ordinary tides in the eastern part of the Strait of Magellan have a rise and fall of 30 feet or more, and the spring tide, 45 or 50 feet, though in the western part of the strait the tides have a much less rise and fall. The great rise and fall of the tides on the Atlantic side cause rapid currents in the strait, often with a velocity of 7 or 8 knots an hour, and these, scouring the beaches backward and forward, must have a very marked effect in concentrating the gold. When we consider that a river, flowing always in one direction, has a wonderful power to concentrate gold in the gravel in its bed, a much

[1] A similar phenomenon is observable in the gold-bearing beach sands of Cape Nome, Alaska.

greater concentrating power would seem to be possessed by a channel like the Strait of Magellan, where the tides run as fast as a very swift river, and where they reverse their direction four times a day; for in water running always one way, gold may become covered and protected from further concentrating action, but in water running first one way and then another, gold that may be covered when the water runs in one direction, may be uncovered and moved about when the direction is reversed, eventually becoming more closely concentrated. In fact, the conditions in the Strait of Magellan represent a natural process of concentration, not at all unlike some of the artificial processes that man has found best suited for concentrating gold.

METHODS OF PROSPECTING

Prospecting in the Strait of Magellan and Tierra del Fuego is a more difficult task than in most places, and many a man has lost his life in his search for gold in that bleak, inhospitable region, while many more have rapidly become discouraged and returned to milder climates. Most of the traveling is done in boats, as the land is much cut up by deep tidewater channels and bays, and covered with dense underbrush or immense peat bogs; while everywhere, even on the mountain sides, the soil is soft and boggy, so that walking is difficult and often impossible. Hence traveling in boats and stopping from place to place along the shore is the most practical way of prospecting; but here again another difficulty comes in, as the storms are frequent and violent, and many a vessel has been hurled on the rocks and everyone in her lost. The climate, however, though stormy, is not extreme in temperature, the thermometer rarely going much below zero or much above 60° Fahrenheit. The mean winter temperature is about 33° F. and the mean summer temperature is about 50° F.

The natives, until recently, have been a considerable check to the progress of mining. Many of them still use the bow and arrow of their ancestors, and have fiercely opposed the invasion of the white man; yet the sad fate of most American Indians is rapidly overtaking them, and they will probably soon vanish before the miners and the cattlemen.

Aside from the difficulties of prospecting, the industrial conditions under which gold is worked in this region are not as expensive as

might at first be supposed. General supplies can be obtained at Punta Arenas at reasonable prices, for it is a seaport and supplies are brought there by ocean steamers at fairly cheap rates. The most expensive item is coal, and this is brought mostly from foreign countries. There is a small deposit of lignitic coal worked at what is known as the Loreto mine, a short distance from Punta Arenas, but the production is very limited and does not go far toward supplying the needs. There is also coal near Coronel and Lota on the Chilean coast, south of Valparaiso, but this is mostly used locally and by ocean steamers. In some parts of Tierra del Fuego there is a good deal of timber of the magnolia, beech, and other varieties, which can be used as fuel, but in other localities it is scarce. All over the region there is a great deal of peat, and efforts are now being made to use this as fuel.

The season during which mining can profitably be carried on is about eight or nine months, from August to May, while during the rest of the year frost and snow hinder operations. The capital at present invested in the industry is mostly Chilean and Argentine, but it seems probable that, as the region becomes better known, other capital may be attracted to the gold deposits of this far-south country. No very definite statistics of the production of gold in the early days in the region are obtainable, but until recently it has been small, and probably not very many hundreds of thousands of dollars had been produced up to the time of the introduction of the steam dredges. With these, however, the production will probably be greatly increased.

THE CAMBRO-ORDOVICIAN LIMESTONES OF THE APPALACHIAN VALLEY IN SOUTHERN PENNSYLVANIA[1]

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The limestones of the Appalachian Valley, which in the South are separated into many formations, have generally been treated as a unit in the North under the name Shenandoah, or other local terms, such as Valley, Lancaster, Kittatinny, and York. These rocks include all the strata between the Cambrian quartzites of Georgian age and the Martinsburg ("Hudson") shale of Ordovician age.

In a paper on the sedimentary rocks of South Mountain[2] the author briefly described the formations comprising the Shenandoah group in southern Pennsylvania. Later studies of these rocks in the Cumberland Valley of Pennsylvania have furnished data for a more complete description of the group, including the faunal content and correlation, based on determinations by E. O. Ulrich.

The formations comprising the Shenandoah group in southern Pennsylvania are as follows:

	Martinsburg formation		Eden Utica Upper Trenton	Ordovician
Shenandoah group	Chambersburg limestone	100–600 feet	Lower Trenton Black River Lowville Upper Chazy	Ordovician
	Stones River limestone	800–1000 feet	Lower and middle Chazy	Ordovician
	Beekmantown limestone	2250–2300 feet	Beekmantown	Ordovician
	Conococheague limestone	1635 ± feet	Saratogan	Cambrian
	Elbrook formation	3000 ± feet	Acadian	Cambrian
	Waynesboro formation	1250 ± feet	Acadian	Cambrian
	Tomstown limestone	1000 ± feet	Georgian	Cambrian
	Antietam sandstone		Georgian	Cambrian

The general structure of the Cumberland Valley is a monocline, the oldest rocks of the Shenandoah group resting against the Cam-

[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] *Jour. of Geol.*, Vol. XIV, 1906, pp. 201–20.

brian quartzites of South Mountain on the east, and the youngest rocks passing beneath the Ordovician shales and sandstones of North Mountain and its associated ridges on the west. The monocline is not simple, however, but is modified by numerous folds and faults that either repeat the strata or conceal them.

The following detailed descriptions relate chiefly to the portion of the Valley in the Mercersburg and Chambersburg 15-minute quadrangles, which lie just north of the Maryland state line, but brief references are made to the Carlisle quadrangle at the north end of South Mountain.

TOMSTOWN LIMESTONE

The Tomstown limestone is not well exposed because of its nearness to South Mountain, where the surface is thickly covered by wash. It is composed largely of limestone, both massive and thin bedded, in part cherty, with some shale interbedded near the base. On account of its relative solubility it forms a depression or valley between the mountain and the irregular line of low ridges and knobs of the Waynesboro formation. Its thickness, computed from the width of its outcrop and the dip of its beds, is about 1,000 feet.

The base of the formation is largely concealed but comprises some hydromica shale interbedded with the limestones resting on the uppermost beds of Antietam sandstone. The top of the formation is placed at the first sandstones of the Waynesboro formation.

In the eastern or Chambersburg quadrangle the Tomstown limestone forms a belt about one mile wide along the foot of South Mountain, spreading out to nearly double that width in places. At Little Antietam Creek it is offset by a diagonal fault and extends up the Antietam Valley into the mountains several miles.

But few fossils have been found in this formation. At Roadside, in the upper limestones of the formation, excellent specimens of *Salterella* sp. undet., with the characteristic invaginate structure, were obtained. Mr. Walcott also found in this limestone, at the foot of the mountain east of Little Antietam Creek, *Kutorginia* n. sp. and fragments of *Olenellus*. These definitely determine its age as Georgian (Lower Cambrian).

In central Virginia a formation 1,600 to 1,800 feet thick, occupying

about the same interval but apparently including beds which in the Chambersburg area are calcareous sandstones and are mapped with the overlying Waynesboro formation, has been named Sherwood limestone by H. D. Campbell. The new name Tomstown is from a village in the Chambersburg quadrangle. The formation has been recognized also in the Carlisle quadrangle to the north, where it forms a deeply weathered belt about the foot of the mountain, largely covered by wash.

WAYNESBORO FORMATION

The Waynesboro formation is a series of sandstones, purple shales, and limestones overlying the Tomstown formation. Because of its resistant siliceous character it forms hills and knobs, parallel to the mountain front. At the base are very siliceous gray limestones that weather to slabby porous sandstone, large round masses of rugose chert, and white vein quartz.

In the middle of the formation are dark-blue to white subcrystalline limestones and dolomites, which become siliceous upward and merge into mottled slabby sandstone and dark-purple siliceous shale at the top. The thickness of the formation, computed from the width of outcrop and dips, and allowing for minor folding, is 1,250 feet.

The formation occupies a belt about one-half mile wide along the east side of the Cumberland Valley in the Chambersburg quadrangle. Its most complete development is in the hills northeast of Waynesboro, from which its name is taken. It has been traced northward beyond Mt. Holly Springs in the Carlisle quadrangle, but is there seldom exposed.

The only fossils found in this formation are a few poorly preserved shells, two of which are identified as *Obolus* (*Lingulella*) sp. undet. They were obtained from sandy shale at the very top of the formation, just east of Waynesboro. They suggest Acadian (Middle Cambrian) age but are not conclusive.

In central Virginia the Buena Vista shale, described by H. D. Campbell, is at this general horizon, but, as previously stated, apparently has a different lower limit. It is described as bright variegated shale, 600 to 900 feet thick, with mottled limestone and shale in the lower part. Mr. Walcott found in it a species of *Ptychoparia* related to Acadian (Middle Cambrian) species of Tennessee.

ELBROOK FORMATION

The Elbrook formation is the thick series of gray to light-blue shaly limestone and calcareous shale that overlies the purple Waynesboro formation.

The formation is decidedly shaly, most of the included limestones being minutely laminated and weather readily into calcareous shaly plates. When unweathered the limestone appears massive and homogeneous and in places is quarried.

Near the middle of the formation are massive beds of dolomite and very siliceous or quartzitic limestone that weathers to porous slabby sandstone and frequently forms knobs and ridges. The formation is limited above by limestone conglomerates containing rounded vitreous quartz grains and others containing tabular fragments of limestone, which characterize the base of the overlying formation.

The thickness of the Elbrook, determined on the two limbs of the unsymmetrical syncline west of Quincy, is about 3,000 feet.

The Elbrook formation crosses the Chambersburg quadrangle in a belt about 2 miles wide, with numerous projections and re-entrants due to intricate folding. It has also been traced across the Carlisle quadrangle where the character of the limestones is the same, but shales increase in prominence.

The only fossils found in this formation were fragments of trilobites obtained from rather pure limestone near the base northeast of Waynesboro. The age of the rocks could not be determined from these fragments, but they suggest Acadian.

The limestone was once extensively quarried for ballast for the Western Maryland Railroad at Elbrook, in the Chambersburg quadrangle, from which the name of the formation is taken.

CONOCOCHEAGUE LIMESTONE

The Conococheague limestone is characterized by beds containing thin sandy laminae and quartz grains that weather into hard shale fragments and thin slabby sandstones which generally give rise to rocky hills and rugged topography.

The base of the formation is usually easily determined because it is marked by siliceous beds and conglomerates that produce a ridge. The conglomerates are of two kinds; one is composed of rounded

limestone pebbles, 1 inch or more in size, in a matrix containing numerous round coarse grains of vitreous quartz; the other is composed of long slender fragments of limestone in a calcareous matrix, which, because the fragments are tilted at various angles, is called "edgewise" bed. Interbedded with the conglomerates are oolites and dark shaly limestones with red clay partings.

The body of the formation is a closely banded dark blue limestone, the bands varying from one-half inch in width to minute laminae. The banding is inconspicuous in the fresh rock but is brought out in weathering as yellowish sandy streaks across a light-blue or gray surface. Toward the top these partings become more numerous and sandy, and weather into hard sandy plates and sheets. Chert is not an important constituent of the formation in the Chambersburg and Mercersburg quadrangles.

The thickness of the formation is about 1,600 feet.

A section measured at Scotland is as follows:

	Rather pure, light, shelly or platy limestone, probably Beekmantown-
90 feet.	Granular crystalline limestone containing coarse "edgewise" conglomerate, oolite, and pink marble, with numerous slaty partings weathering to glistening shale particles.
300 feet.	Covered.
15 feet.	Fine-grained, pure, light limestone, "edgewise" conglomerate and cross-bedded limestone containing quartz grains
390 feet.	Covered. Lower portion contains impure dark limestone and large banded chert.
10 feet.	Banded, dark and light limestone.
270 feet.	Dark, rather pure limestone containing trilobites and oolite, with argillaceous partings weathering to soft shale or slaty partings.
40 feet.	Massive light-colored, dense, even-grained limestone, with few fluted siliceous partings.
70 feet.	Covered.
180 feet.	Corrugated impure siliceous banded limestone and hackly shaly limestone.
30 feet.	Dense, black, rather pure limestone.
40 feet.	Massive beds of crumpled, siliceous banded limestone.
200± feet.	Dense siliceous banded limestone with "edgewise" conglomerate, cryptozoan, and sandstone beds at the base.
1635 feet, total.	

The Conococheague limestone occurs in a broad sinuous belt crossing the Chambersburg quadrangle from south to north. It is plicated into many folds northwest of Waynesboro, marked by ridges of rough topography, and just south of the Chambersburg pike its

basal member forms a high elbow ridge, which is faulted off on the west side.

A wedge-shaped inlier of Conococheague is brought to the surface by an anticline in the vicinity of Welsh Run, in the Mercersburg quadrangle, where the rocks are similar to those in the Chambersburg area, but the siliceous banding is less pronounced. In the Carlisle quadrangle neither the basal siliceous beds nor the sandy laminated beds at the top are prominently developed.

Few fossils have been found in this formation, and such as have been collected are poorly preserved and difficult of determination. At the base a few good specimens of trilobites and brachiopods were obtained in the western portion of Scotland, and fragments of the same were seen in the basal conglomerate. These comprise *Dikelocephalus hartii* Walcott; *D.* sp. undet.; and *Billingsella* like *B. desmopleura*. The trilobites place this part of the formation definitely in the Saratogan (Upper Cambrian). In the basal conglomeratic beds a species of *Cryptozoan*, probably *C. prolijerum* Hall, characterized by a mammiferous surface, the elevations ½ to 1 inch in diameter, is rather generally present. In cross section the fossil appears to consist of thin closely folded laminae, and is illustrated in the writer's former paper.[1]

These siliceous banded limestones, together with overlying finely laminated purer rocks, were previously described by the writer under the name Knox limestone. The differentiation of the upper rocks as a separate formation, next to be described, necessitates the giving of a new name to these lower beds, and Conococheague, the name of the large stream on the banks of which, in the town of Scotland, the best exposures occur, has been selected. The Conococheague and the overlying Beekmantown, therefore, comprise the Knox group.

BEEKMANTOWN LIMESTONE

The Beekmantown is a rather pure limestone lying between the siliceous Conococheague below and the very pure Stones River above. A minutely laminated appearance on weathered surfaces of many of the beds, due to their impurities, and pink to white fine-grained limestone or marble are characteristic features of the formation. Near

[1] *Loc. cit.* p. 217.

the base are siliceous banded beds and large "edgewise" conglomerate, closely resembling the Conococheague formation. These have been separated as a transition phase under the name Stonehenge member of the Beekmantown.

The best exposure of the formation in the Chambersburg quadrangle is adjoining the Chambersburg-Gettysburg pike, where the following composite section has been measured by Mr. Ulrich and the writer.

Beekmantown Section, 1 Mile East of Chambersburg.

	Base of Stones River containing fine limestone conglomerate and laminar and oolitic chert.	
600 feet.	Interbedded fine-grained pure limestones and magnesian limestones, finely laminated in part and containing small quartz geodes. Porous sandy chert near top. Dark layers near base, mottled by magnesian material that weathers out, leaving pits and holes, contain numerous gasteropods and ostracoda.	
375 feet.	Alternating pure dove and gray limestones and magnesian limestones, with layer of sandy chert.	
100 feet.	Bluish to dove fine-grained fossiliferous limestone, at the base containing rounded quartz grains.	
275 feet.	Pink, fine grained marble, containing layers of milky quartz chert. Gasteropods of the genus Ophileta, Maclurea, and Eccyliopterus rather abundant.	
285 feet.	Pure dove and blue, fine-grained limestone, with some pink limestones. Contains fragments of Trilobites.	
145 feet.	Fine-grained dove to dark-gray limestone with fine conglomeratic and oolitic beds. Abundant chert in upper portion, in part oolitic and conglomeratic.	
225 feet.	Fine-grained light- to dark-gray limestone containing contorted laminae of sandy matter, that stand in relief or fall to sandy shale on weathering, and thick beds of "edgewise" conglomerate. Contain Gasteropods in upper portion and fine fragments of Trilobites in lower part.	Stonehenge member
260 feet.	Dark- to light-gray limestone, with sandy laminae less developed than in overlying beds. Contain Orthis, Ophileta, and Trilobite fragments.	
	Top of Conococheague, containing contorted sandy laminae and beds of coarse limestone conglomerate.	

2,265 feet total.

In the Mercersburg quadrangle an excellent section of the Beek-

mantown occurs on Licking Creek near its mouth. Unfortunately the upper part of the formation is not exposed in the creek bank and is complicated by folding. The section measured by Mr. Ulrich and the writer is as follows:

Beekmantown Section, near Mouth of Licking Creek.

	Interbedded pure and magnesian limestones of Stones River type.
340 feet.	Light gray finely laminated magnesian limestone and white dolomite, with cherts of rosette type at the top.
140 feet.	Dark and light, coarse dolomite.
	Rocks here folded and largely covered; contains white domolite, dark-blue oolitic limestone, and dark coarse dolomite with yellow blocky sandstone fragments and rosette cherts. Exact continuity indeterminable, but the previous beds are apparently repeated by folding.
350 feet.	Interbedded pure and magnesian limestones, with beds of coarse dark dolomite, and in the lower part beds of "edgewise" conglomerate; at base contains Gasteropods, Cephalopods, and Trilobites.
170 feet.	Largely finely banded magnesian limestone with few pure limestones. Contains fine conglomerate beds and Gasteropods.
130 feet.	Largely dolomite, some coarse and dark. Large scoriaceous black chert and coarse sandstone at the base.
290 feet.	Chiefly dolomite, coarse and dark in upper part, with occasional pure fossiliferous limestone. Bed of granular limestone with numerous Ophileta and pinkish fine-grained limestone near middle, crossbedded banded limestone at base locally unconformable on underlying beds.
65 feet.	Fine-grained limestone seamed with calcite and dolomite beds, with flinty chert containing Cryptozoan at the base.
130 feet.	Partly covered. Lower part pure dark limestone with few beds of finely laminated magnesian limestone and fine white oolite near base. Small rough chert with casts of crystal at the base.
165 feet.	Light-blue limestone with fine contorted sandy laminae that weather in relief. Contains fine dark conglomerate with red limestone pebbles and fragments of Trilobites.
530 feet.	Purer fine even-grain limestone with few sandy partings.
	Sandy laminated limestone, much contorted, of the Conococheague formation.
2,310 feet, total.	

The details of the sections in the two areas are quite unlike. Whereas beds of pure limestone and marble are common and chert infrequent in the Chambersburg section, the reverse is true in the Licking Creek section. The pure limestones have been extensively

quarried at Stoufferstown and Stonehenge east of Chambersburg. In the Mercersburg quadrangle, chert is sufficiently plentiful in the soil derived from the Beekmantown to produce low ridges. One horizon is just above the siliceous banded limestone of the Stonehenge member and in the Mercersburg area is included with the siliceous phase. The cherts are of various forms. Some are large, rough, scoriaceous masses, others are flinty in texture, banded, brecciated, granular, and oolitic; while the most unique forms are composed of super-imposed rosettes resembling heads of cauliflower. A Cryptozoan, apparently of the species described by Winchell as *C. minnesotensae*, occurs in these cherts.

An upper horizon of cherts, many of the small rosette form, occurs at the top of the Beekmantown in both areas, but is a ridge maker in the Mercersburg quadrangle.

The Beekmantown limestone is one of the most widely distributed formations in the area, occurring in a broad belt across the western half of the Chambersburg quadrangle, and in several anticlinal areas in the Mercersburg quadrangle. Its outcrops are generally deeply covered with soil with infrequent exposures, and furnish excellent farm land.

In the eastern belt it is closely folded in common with the enclosing limestones, and its outcrop is consequently very irregular in outline and width. In the Mercersburg quadrangle it forms large lens-shaped areas in the anticlinal uplifts of Welsh Run-Edenville, Mercersburg, Foltz, and McConnellsburg.

Although its fauna has been previously observed at various places in the Appalachian Valley, the Beekmantown has not heretofore been recognized as a distinct formation in this region, and little is known of its extent beyond the immediate vicinity of the area. It is known to maintain its lithologic and faunal characters as far northeast as Mechanicsburg, Pa. Although sparingly fossiliferous as a whole, a rather large variety of forms have been collected in this area.

The lower portion of the formation, including the Stonehenge member, is characterized by *Ophileta complanata* and of the 13 species collected the following have been identified by Mr. Ulrich:

Rhabdaria, cf. R. fragilis Billings.
Calathium sp. undet.
Orthis wemplei?
Ophileta complanata.
Maclurea affinis.
Eccyliopterus.
E. triangulus.
Bathyurus near B. conicus.

In the middle of the formation two faunas have been distinguished. The lower one, characterized by horn-like *Opercula*, small *Isochilina*, *Hormotoma artemesia*, and large thin-shelled *Maclurea*, occurs in both quadrangles and good collections were made at Licking Creek and near McConnellsburg. 15 species were collected of which the following have been tentatively determined:

Orthis cf. electra.
Maclurea affinis.
Horn-like opercula of an otherwise unknown gasteropod for which Mr. Ulrich suggests the generic name *Ceratopea*.
Liospira canadensis.
Eccyliopterus, cf. triangulus.
Isotelus canalis.
Bathyurus cf. conicus.
B. caudatus.
Amphion cf. salteri.
Leperditia cf. Primitia gregaria Whitfield.

The upper fauna of the middle division, characterized by *Syntrophia lateralis* and found only at Stoufferstown, is as follows:

Syntrophia lateralis.
Maclurea? sordida.
Liospira cf. laurentina.
Orthoceras cf. primigenium.

In the upper part of the formation, which is characterized by high-spired turritelloid gasteropods and by *Ophileta disjuncta*, 17 species have been collected from the quarry at Stoufferstown, and the following tentatively identified by Mr. Ulrich:

Orthis (? Dalmanella) electra.
Maclurea cf. M. oceana.
Ophileta ? disjuncta.
Solenospira cf. prisca.
Turritoma acrea?
Hormotoma gracilens.
Lophospira cf. Murchisonia gregaria Billings.
Cyrtocerina cf. mercurius.
Trocholites internestriatus.

Mr. Ulrich, who determined all the fossils described under this and succeeding headings, correlates the foregoing lists with the Beekmantown of New York, and that name is therefore applied to the formation.

STONES RIVER LIMESTONE

Above the Beekmantown is a considerable thickness of very pure limestones with occasional magnesian layers. The greater portion of the limestone that is burned for lime in this area is obtained from

this formation. In general the formation is composed of three divisions:—a middle band of massive pure granular limestone containing the large gasteropod *Maclurea magna* and thin beds of black chert that weather into small rectangular blocks; an upper series of thin-bedded pure limestone; a lower series of interbedded massive pure beds and magnesian layers.

These divisions cannot be readily distinguished in all parts of the area, and at no place can the complete section be seen because the beds are several times repeated by folding and the outcrops are not continuously exposed.

The following is a composite section of the formation in the Chambersburg belt:

	Feet
Thin-bedded, fine-grained, pure, dove limestone.	275+
Massive pure limestone containing Maclurea magna and black chert layers. Upper part, compact, blue to dark; lower part, light gray, granular and oolitic	150–200
Massive and thin-bedded limestone interbedded with magnesian layers	600+
Total	1050+

In the western belts the cherty Maclurea horizon was not clearly observed and the three-fold division could not be made. At West Branch of Conococheague Creek, south of the Mercersburg-Greencastle pike, its thickness was determined at 800 to 1,000 feet.

In McConnellsburg Cove, west of Tuscarora Mountain, the exposures are exceptionally meager. At a quarry south of the Mercersburg pike the formation as exposed comprises about 575 feet of interbedded, pure and banded magnesian beds with very pure fine-grained dove limestone at the top.

The formation crosses the Mercersburg and Chambersburg quadrangles from north to south in five belts. The eastern belt lying in the Chambersburg quadrangle is intricately folded and faulted, and comprises several parallel strips.

In the next limestone belt to the west, the Welsh Run-Edenville anticline, the Stones River forms a narrow strip about ¼ mile in width on either side of the Beekmantown. In the Mercersburg belt it occurs as two narrow faulted strips. In the Foltz and McConnellsburg limestone belts, its outcrops are largely covered.

Few fossils have been found in this formation, except in the middle chert-bearing portion. These consist chiefly of gasteropods, ostracoda, cephalopods, and bryozoa. A few ostracoda (*Leperditia fabulites*) and *Tetradium "syringoporoides"* can usually be obtained from the fine even-grained beds in all parts of the formation; 22 species were obtained from the subgranular beds of the middle division, and the following have been tentatively identified by Mr. Ulrich:

Stromatocerium sp. nov.
Tetradium "syringoporoides"—the single-tubed form of this genus so characteristic of the Stones River.
Glyptocystites sp. undet.
Lingulella ? belli (Billings)
Hebertella borealis.
H. vulgaris
Dinorthis cf. platys.
Strophomena aff. S. charlottae.
Bucania sulcatina.
Maclurea magna.
Lophospira bicincta.
Isochilina cf. amiana.
Ampyx halli.

The massive shells and opercula of *Maclurea magna* are the most characteristic fossils of this division. From the standpoint of correlation the most noteworthy feature of the above list is that no less than eight of the species occur in the middle Chazy of the Champlain Valley.

Although only *Leperditia fabulites*, L. cf. *amiana*, *and Lingula manteli* were obtained from the lower beds of this formation in this area, 12 species were collected 30 miles down the valley at Martinsburg, W. Va., by Mr. Ulrich and the writer, of which the following have been determined:

Solenopora compacta var.
Cyrtodonta sp. nov.
Matheria sp. nov.
Liospira cf. obtusa.
Lophospira cf. perangulata.
Helicotoma ? sp. nov.
Oncoceras ? sp. undet.
Leperditia fabulites.

The fossils as well as the lithologic character of this formation are so nearly the same as those of the Stones River limestone of Tennessee that they are regarded by Mr. Ulrich as identical, and the name Stones River is therefore applied.

CHAMBERSBURG LIMESTONE

The Chambersburg limestone is the uppermost division of the Shenandoah limestone. It is characterized throughout the area by

fossiliferous thin-bedded limestones with argillaceous partings. It varies in thickness across the strike from a maximum of 600 feet in the Chambersburg belt to about 100 feet in the McConnellsburg Cove.

Its most typical development is in the Chambersburg belt throughout which fossils are abundant. The following section in the railroad cut 1½ miles west of Kauffman is the most complete continuous section in this belt.

	Feet
Black shale (Martinsburg)	
Largely concealed, but probably chiefly shale (near the top are black carbonaceous limestone with conchoidal fracture, shaly dark crystalline limestone, thin sandstone, and 10 feet of coarse crystalline limestone containing Lingulas)	150
Calcareous shale and limestone	100
Nodular clayey limestone	50
Dark platy limestone	94
Compact dark limestone, very fossiliferous	108
Cobbly limestone containing numerous Nidulites, bryozoa, and a layer of cystid heads	105
Total	607

The "cobbly" character of the weathered outcrop of certain of the beds, due to a wavy lamination or clay parting that crosses the bedding at a high angle and, on weathering, gives rise to rounded lenticular masses resembling rough cobbles, is one of the noticeable features of this formation. The upper 200 feet of the formation is composed largely of shale with interbedded thin fossiliferous limestones.

In the Welsh Run-Edenville belt, 2½ miles southeast of Mercersburg, the following section occurs on the banks of West Branch of Conococheague Creek.

	Feet
Fissile shale containing graptolites and lingulas Calcareous black shale and hard thin black carbonaceous limestones, 80 feet. } Martinsburg shale.	
Granocrystalline limestone, fossiliferous	2
Cobbly dark subcrystalline limestone, both massive and thin-bedded	73
Coarse massive granocrystalline limestone with massive beds of pure fine-grained limestone	75

Platy granocrystalline limestone, fossiliferous	25
Dark, subcrystalline limestone with wavy partings of shale, fossiliferous	150
Very thin-bedded pure fine-grained drab limestone followed by more massive pure beds with magnesian layers and fine laminations (Stones River)	
Total	325

The following section was measured 1½ miles west of Markes on the west side of the Mercersburg belt:

	Feet
Fissile and calcareous shale (Martinsburg)	
Thick bed of coarse crystalline gray limestone, fossiliferous	5
Thin bedded and cobbly dark limestone with Nidulites and *Monotrypa hemisphericus* in upper part	45
More massive limestone, banded in part	45
Pure fine-grained dark limestone with large Beatricea	20
Dark compact limestone	20
Covered	60+
Thin-bedded pure fine even-grained drab limestone (Stones River)	150
Total	195+

In the McConnellsburg Cove, few outcrops of the Chambersburg limestone occur, and but one measured section was secured, 2 miles northeast of McConnellsburg, as follows:

	Feet
Fissile shale containing graptolites	
Hard black slate and thin slaty black limestone, (Martinsburg)	84
Covered	10
Gray marble and massive blue-veined limestone	20
Dark shaly limestone with argillaceous partings, containing solenopora and bryozoa	68
Pure fine even-grained limestone (Stones River)	
Total	182

The Chambersburg formation forms a narrow band along the margin of the overlying Martinsburg shale throughout the Mercersburg and Chambersburg quadrangles except where it is cut out by faults. It is present also along this contact throughout the Carlisle quadrangle, but details of its character and thickness there are not known.

Nearly everywhere this formation yields on careful search an abundance and great variety of fossils, and those from the Chambersburg quadrangle differ from those obtained in the Mercersburg quad-

rangle. In the Chambersburg belt the formation may be divided into 4 faunal zones.

From the lower zone, characterized by *Dinorthis pectinella*, 20 species were collected, of which the following have been determined by Mr. Ulrich:

Receptaculites cf. occidentalis.
Echinosphaerites sp. undet.
Orocystites?
? Chaetetes cumulata.
Hemiphragma irrasum.
Dalmanella testudinaria, small n. var.
Dinorthis pectinella.
Hebertella bellarugosa.
H. cf. borealis and vulgaris.
Rafinesquina inquassa?
Plectambonites pisum var.
Triplesia n. sp.
Leperditia fabulites pinguis.
Ampyx normalis.

In the second division, characterized by Nidulites, 38 species were collected and the following tentatively identified:

Nidulites cf. favus.
New genus of Amygdalocystidae.
New genus of Pleurocystidae.
Bolboporites n. sp.
Praspora contigua.
P. cf. lenticularis.
Stromatotrypa (? Diplotryna) sp. undet.
Hemiphragma irrasum?
Stomatopora inflata.
S. proutana.
Orthis sp. undet.
Plectorthis n. sp.
Dalmanella testudinaria var.
Dalmanella n. sp. (aff. D. subaequata).
Scenidium anthonense.
Strophomena cf. filitexta.
Rafinesquina cf. inquassa.
R. cf. incrassata.
Leptaena n. sp.
Plectambonites cf. pisum.
P. asper (Reudemann).
Triplesia n. sp.
Ampyx n. sp. (cf. A. normalis and A. halli).
Pterygometopus cf. callicephalus (variety approaching P. schmidti).
Ceraurus pleuraxanthemus.

In the third division, which is often crowded with fossils, 43 species were collected, of which the following have been determined:

Diplotrypa sp. undet.
Rhinidictya cf. neglecta.
Plectambonites n. sp.
Leptaena n. sp.
Parastrophia cf. hemiplicata.
Ulrichospira n. sp.
Echinosphaerites sp.
Hemiphragma cf. irrasum and ottawaensis.
Arthropora cf. bifurcata.
Rhinidictya cf. neglecta.
cf. Trematopora ? primigenia.
Orbiculoidea cf. lamellosa.
Orthis cf. tricenaria.
Scenidium cf. (Merope).
Dinorthis n. sp. (aff. D. subquadrata).
Strophomena n. sp.

Strophomena (? Leptaena) cf. charlottae.
Plectambonites asper.
P. pisum.
P. n. sp. (near P. pisum).
P. n. sp.
Christiania trentonensis.
C. n. sp.
Triplesia n. sp.
T. cf. nucleus.
Protozyga exigua.
Orthoceras cf. junceum.
O. cf. arcuoliratum.
Lepidocoleus 2 undet. species (near L. jamesi).
Isotelus cf. gigas.
Illaenus consimilis.
Fragments of Trinucleus or Tretaspis.

In the upper, or Sinuites, zone, which is immediately beneath graptolite-bearing shales, 31 species were collected, and the following determined:

Diplograptus sp. undet.
Lingula riciniformis ?
Lingulops sp. nov. ?
Conotreta rusti.
Rafinesquina cf. ulrichi.
Sinuites cancellatus.
Cyclora minuta.
C. parvula.
Microceras cf. inornatum.
Coleolus cf.
Trocholites sp. undet.
Caryocaris sp. undet.
Turrilepas sp. undet.
Ctenobolbina sp. undet.
Ampyx n. sp.
Trinucleus concentricus ?
Harpina ottawaensis ?
Triarthrus becki.
T. fischeri.
Calymene senaria ?
Bumastus sp. ?
Bronteopsis ? sp. undet.
Proetus latimarginatus.
Cyphapis matutina.

In the Mercersburg quadrangle 4 faunal zones are also distinguished but they do not correspond with those of the Chambersburg belt. The lower zone comprises 20 species, largely new and undescribed, of which the following are tentatively listed:

Licrophycus cf. ottawaensis.
Lockeia sp. undet.
Cliocrinus n. sp. ?
Raphanocrinus ? n. sp.
Echinosphaerites sp. ? plates only.
Helopora spiniformis ?
Rhinidictya neglecta.
Escharopora ramosa.
Dalmanella cf. testudinaria.
D. subaequata.
Rafinesquina minnesotensis.
Strophomena cf. filitexta.
Plectambonites asper.
Gonioceras chazyense.
Thaleops ovatus.
Pterygometopus cf. schmidti.

Of the 48 species collected in the second zone, the brachiopods and bryozoa that have been identified by Mr. Ulrich are regarded by him as suggesting the upper Chazy of New York:—

Solenopora compacta.
Camarocladia cf. rugosum.
Columnaria halli.
Tetradium columnare.
T. cellulosum.
Caryocystites sp. nov.
Anolotichia impolita.
Nicholsonella laminata.
Batostoma cf. magnopora.
Hemiphragma irrasum.
Helopora divaricata ?
Rhinidictya fidelis.
Pachydictya cf. foliata and robusta.
Escharopora confluens.
Phylloporina reticulata.
Hebertella borealis.
H. vulgaris.
H. bellarugosa ?
Rafinesquina sp. undet.
Strophomena (? Leptaena) charlottae.
Plectambonites asper.
Rhynchonella plena.
Zygospira recurvirostris.
Leperditia cf. fabulites.
Isochilina cf. gracilis.
Platymetopus cf. trentonensis.

The third zone, characterized by Beatricea, is regarded as representing the Lowville ("Birdseye") of New York. Of the 37 species, the following have been identified.

Beatricea n. sp.
Tetradium cellulosum.
Echinosphaerites sp.
Mesotrypa ? sp. undet.
Diplotrypa ? sp. undet.
Stictoporella sp. undet.
Dinorthis cf. meedsi.
Triplesia sp. nov.
Zygospira uphami.
Helicotoma planulatoides.
H. verticalis ?
Omospira cf. alexandra.
Leperditia cf. fabulites.
Isochilina n. sp. (cf. I. gracilis).
I. n. sp. (cf. I. ottawa).
Macronotella ulrichi.
Drepanella macra.

The upper division is the Sinuites zone, and although it corresponds with the upper zone of the Chambersburg belt, it is not succeeded directly by the graptolite-bearing shale but by a considerable thickness of intervening barren calcareous shales and thin black limestones. Of the 32 species the following have been identified by Mr. Ulrich, who correlates them with the Normanskill division of the Trenton of New York.

Hindia sp. undet.
Lingula riciniformis.
Lingulops n. sp.
Dalmanella n. sp.
Dinorthis cf. germana and subquadrata.
Plectambonites pisum.
P. n. sp. (1) (aff. P. transversalis).
P. n. sp. (1) (aff. P. sericea).
Christiania n. sp.
Triplesia n. sp.
Sinuites cancellatus.
Cyrtolitina nitidula.
Eccyliomphalus spiralis.
Strophostylus textilis.
Cyclora minuta.
C. depressa ?
Orthoceras junceum.
Trinucleus concentricus ?
Cyphaspis matutina.

NORTH AMERICAN PLESIOSAURS
TRINACROMERUM

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In previous papers[1] I have discussed the known characters of *Elasmosaurus*, *Cimoliasaurus*, *Brachauchenius* and *Polycotylus*, and *Trinacromerum*, as derived from the species *T.* (*Dolichorhynchops*) *osborni*. The brief and somewhat erroneous description of the type of *Trinacromerum* by its author has hitherto prevented its recognition with much certainty. Its relationships with *Dolichorhynchops* I recognized at the time that I proposed that genus, and suggested the possible identity, but it was not until I had the opportunity of examining the type specimen of *Trinacromerum*, which was kindly granted by the president of Colorado College, where the specimen is now preserved, that I became assured of the synonymy, an acknowledgment of which was made in the third volume of Chamberlin and Salisbury's *Geology*, and, later, in the second of the papers cited below. Furthermore, I am now nearly as well assured of the synonymy of *Trinacromerum* with *Polycotylus*, but am yet hesitant to abandon the name *Trinacromerum* until the skull of the type species of *Polycotylus*, (*P. latipennis* Cope) shall be better known and have been more thoroughly studied. The only differences that I can so far discover are the deeper concavity of the vertebral centra, the number of epipodials and the manner of attachment of chevrons—of doubtful value. The name *Trinacromerum*, therefore, is used provisionally until such time as more positive evidence is forthcoming.

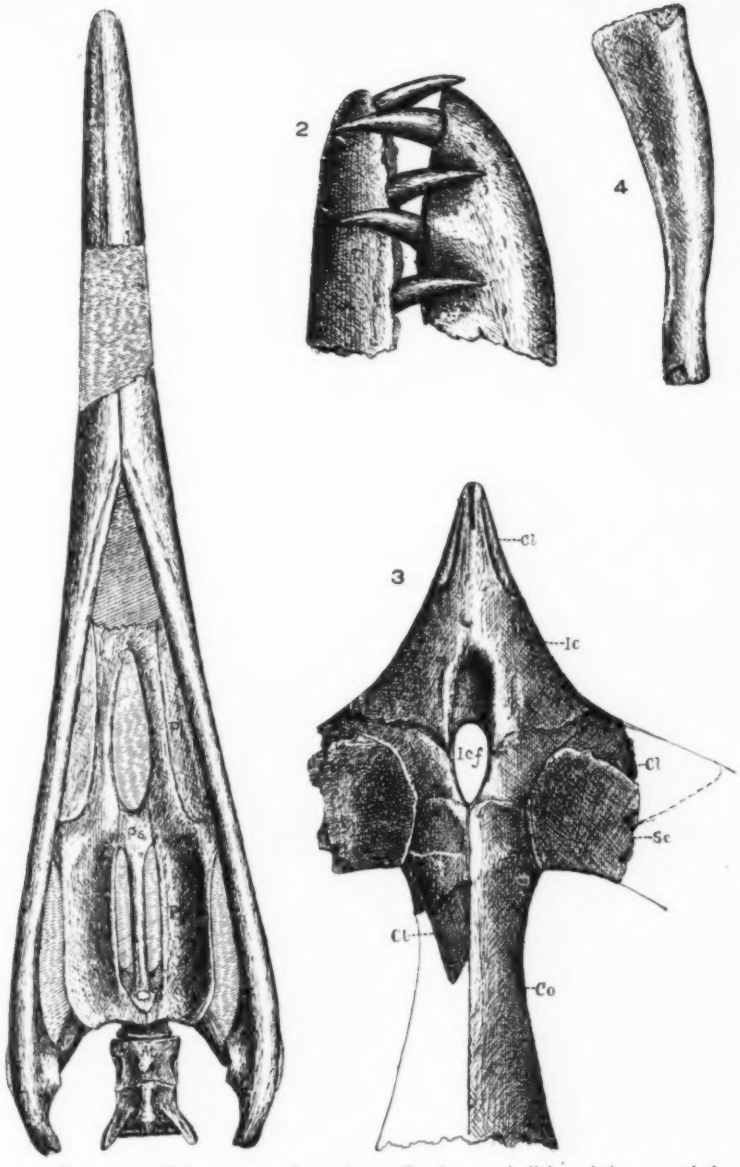
Very recently, through the courtesy of Professor Sclater, I have had the opportunity of further study of certain important parts of the type specimen of *Trinacromerum bentonianum*, kindly sent me for that purpose. I am thus enabled to give a number of figures and a more complete description of this important species.

[1] *Publication No. 73* of the Field Columbian Museum, 1903; *American Journal of Science*, XXI, 221, 1906; *Proc. U. S. Nat. Mus.*, XXXII, 477, 1907.

Trinacromerum bentonianum Cragin

Skull.—In his original description Cragin speaks of three skulls referred by him to his typical species. One of his skulls, however, proves to be a part of the pectoral girdle of his original type, an error resulting from the confusion of the interclavicular foramen with the pineal foramen, an error not so great as it would seem, since such a foramen in the pectoral girdle was unknown previously among plesiosaurs. A close comparison of the two skulls, both from the same horizon and adjacent localities, leaves no doubt of their identity, both generically and specifically. Skull "No. 2," the better specimen, shows the underside nearly complete, with the hyoids and jaws in place, a small part of the facial portion only, wanting. The upper part of the skull is so badly compressed and mutilated that but little decisive can be made out from it, but the palatal structure, perhaps the most important of the plesiosaur cranial anatomy, has been determined from this specimen almost perfectly, the relations of the vomers only being doubtful (figs. 1, 2).

The slender parasphenoid separates two long and narrow openings between the pterygoids, which openings may properly be called the parasphenoidal vacuities for the present. On either side, the long, broad, gently concave plate of the pterygoid fills up nearly all the free space between the vacuity and the mandible, and thence extends forward as a slender process on either side of the real interpterygoidal vacuity to articulate externally with the palatine, and anteriorly, doubtless as in *T. osborni*, with the vomer. The true interpterygoidal vacuity is an elongated ovate opening, obtuse posteriorly, acute in front, bounded by thickened, rounded margins; posteriorly it is bordered by the slightly expanded anterior end of the parasphenoid, which is here concave in outline and thick, the pterygoid suture extending forward on each side from the front end of each parasphenoidal vacuity. In the type specimen of *T. osborni* the anterior end of this bone was somewhat mutilated, and I was not quite certain that it was not produced forward to fill up this vacuity as in other known plesiosaurs. This, however, is not the case. This extraordinary opening is therefore unique for this genus and *Polycotylus* among plesiosaurs, and indeed among all known reptiles, if it be merely a vacuity. And I venture the opinion that it may be compared with a similar opening



FIGS. 1–4.— *Trinacromerum bentonianum* Cragin. 1, skull from below, one-sixth natural size; 2, extremity of beak, one-half natural size; 3, pectoral girdle in part one-sixth natural size; 4, left hyoid from below. At, atlas; Cl, clavicle, Co, coracoid; Ic, interclavicle; Icf, interclavicular foramen; Pl, palatine; Ps, parasphenoid; Pt, pterygoid; Sc, scapula.

in the skull of *Nyctosaurus* and *Pteranodon*, the American Cretaceous pterodactyls. This would suggest that the supposed elongated basisphenoid of *Nyctosaurus* is really the parasphenoid, against which view we have the improbability of the survival of so large a parasphenoid in this type of reptiles, as well as the mode of attachment of the pterygoids on either side.

The junction of the transpalatine is seen in the specimen on the left side, but the shape and relations of the bone are obscured by the mandible, though certainly there is no posterior palatine foramen; doubtless the relations of the bone are quite as I have figured them in *T. osborni*.

The relations of the pterygoids posteriorly cannot certainly be made

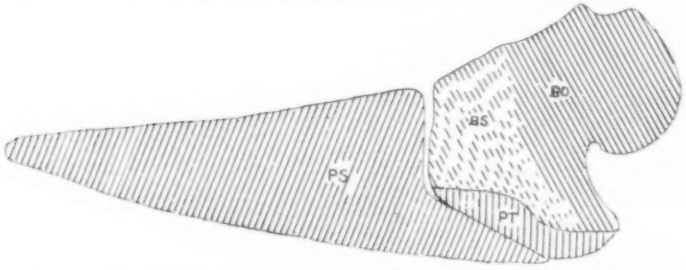


FIG. 5.—*T. bentonianum*. Section through basioccipital and parasphenoid, one-half natural size. BO basioccipital; BS, basisphenoid; PS, parasphenoid; PT, pterygoid.

out in skull "No. 2" nor were they in the type of *T. osborni*. Very fortunately, however, the posterior part of skull "No. 1," the type specimen of the genus, gives nearly all the information that could be desired. In this specimen there is a longitudinal break or split through the occipital condyle, nearly in the middle line, to the interpterygoidal vacuity. I give this section in fig. 5. The distinction between the basioccipital and basisphenoid is not clear, but it must be as in *T. osborni* or nearly so, as has been indicated by the broken lines of the figure. In front of the basisphenoid the conical and thickened parasphenoid, or "presphenoid" narrows into a median, long, and vertically broad bone to the hind end of the interpterygoidal vacuity, which it bounds. Posteriorly it extends, by a squamous underlap, nearly to the hind margin of the basioccipital, the

united pterygoids clearly intercalated between them. Between the pterygoids and parasphenoid, and hollowed from the latter there appear to be two parallel canals, terminating on the free surface below. Along the middle of the rounded under surface of the parasphenoid there is seen a slender groove, as though the remains of a suture, a remarkable thing if it be really a suture. The parasphenoidal vacuities are bounded outwardly by the everted margins of the pterygoids, internally by the parasphenoid. The openings, however, do not quite reach to the hind end of the external boundaries, the pterygoids forming a floor to the grooves on the posterior fourth, as seen from below. So extraordinary a development of the parasphenoid in this group of reptiles as is shown in these specimens is of more than passing interest. If it be the true vomer of the mammals, one cannot understand the cause of its retention in so highly developed a condition unless the plesiosaurs sprang from reptiles that had not yet lost it. The Nothosauria are markedly different in the complete union of the pterygoids on the median line, to the exclusion, not only of the parasphenoid but the basisphenoid also; a condition, which, associated with the typical reptilian phalangeal formula, excludes the group I believe absolutely from direct and perhaps indirect genetic relationships with the plesiosaurs. Furthermore, the persistent retention of the parasphenoidal vacuities, so definitely bounded in all plesiosaurs, is puzzling, unless the explanation is that suggested by me in my earlier paper—that they are the real nareal openings.

The crushed condition of the upper part of the skull is such that little definite can be made out, though the resemblance to the same parts in *T. osborni* is evident. On the left side the jugal arch has been but little disturbed, showing the jugo-postorbito-squamosal sutures as in *T. osborni*. There is no indication whatever, and the parts are here intact, of a quadratojugal bone, the supposed suture of *T. osborni* being in no wise apparent. I believe that at last it may be definitely said that the quadratojugal bone is ***absent in all plesiosaurs***, as a distinct element.

Unfortunately the jumbled condition of the frontal and prefrontal elements in these skulls has obliterated all sutures. An examination, however, of the various plesiosaur skulls in the British Museum and

at Cambridge, confirms me, in the determination of the elements in *Brachauchenius* and *Trinacromerum*. That this was not the frontal structure in all plesiosaurs is also quite certain. As I have stated before, the suture between the frontal bone and the element directly in front of it had never been positively determined. A suture has been given for the skull of *Plesiosaurus macrocephalus*, nearly transverse in position and immediately in front of the pineal opening, but this is incorrect. However, an isolated specimen of the frontal region of a species of *Plesiosaurus* in the British Museum, for the privilege of examining which I am indebted to Dr. Woodward, shows clearly a fronto-parietal suture, beginning some distance in front of the pineal opening, in the middle line, and extending obliquely outward and forward, clearly distinguishing a median frontal bone; and the one at either side of this true frontal is as clearly the prefrontal. In the later plesiosaurs, or some of them, I believe that the prolongation of this parietal projection forward to the backwardly produced premaxilla has separated the real frontals; and this interpretation is confirmed by the examination of the bones of this region in *T. anonymum* described farther on.

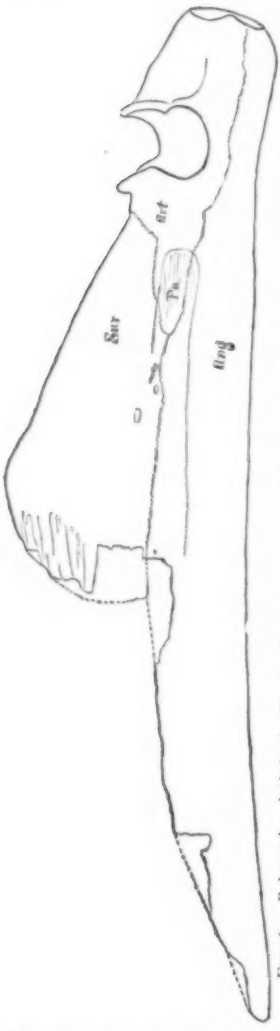


FIG. 6.—*Polycotylus latipinnis* Cope. Posterior part of right mandible, two-sevenths natural size. Art, articular; Ang, angular; Pa, prearticular; Sur, surangular.

Mandible.—The structure of the mandible is, for the first time, completely made out in a specimen (No. 1125) in the Yale Museum. Although the specimen belongs to the closely allied, possibly identical genus *Polycotylus*, it may be described here. The suture between the articular and surangular, never before determined, is here clearly shown, running obliquely downward and forward from just in front of the cotylus to connect with the angular-surangular suture beneath the proximal end of the prearticular (fig. 6). In the earlier of the cited papers I recognized the differentiation of this element in front of the articular, clearly homologous with the 'splenial' of the turtles, and gave to it the name prearticular. Baur, who had previously recognized this new element in the reptilian mandible unfortunately took for the type of structure that of the turtles, and changed the names of the other elements to conform thereto, giving to the splenial, as the name was originally applied, the name presplenial. This confusion was pointed out in a later publication by me, but without mentioning the fact that I had previously proposed the term prearticular for the newly discovered element.[1] Kingsley later, in reviewing the mandibular structure proposed for the same element the term dermarticular. In this separation of the prearticular from the articular the plesiosaurs show certain relationships with the turtles, but not important ones, since a like condition will probably be found in most of the early reptiles. The great elongation of the coronary, and its union in a median symphysis is the most striking characteristic of the plesiosaur mandible.

Hyoids.—Under each skull are preserved in perfect condition, and in undisturbed positions the hyoids. They lie below the concave lateral pterygoid plates, the anterior end reaching nearly as far forward as the hind end of the interpterygoidal opening. The bones of skull No. 2 (fig. 4) are a little less slender than those of skull No. 1. The posterior end is rounded, rod-like, and the mesial border is the thinner and more concave one. The hyoids have hitherto been unknown, so far as I am aware, in the plesiosaurs.

Vertebrae.—The atlas and axis are united with each other and with the occipital condyle in the type specimen. They resemble very closely the same bones in *T. osborni*. The axial rib is firmly attached.

[1] *Field Mus. Publ.*, No. 73, p. 30.

On the underside of the atlantal intercentrum, beyond the middle antero-posteriorly, there is an obtuse hypopophysis with the sides concave. The axial intercentrum has an obtuse keel, thicker posteriorly; this bone, also, is proportionally a little longer than in *T. osborni*. Ten or twelve other cervical vertebrae are preserved, but are, for the most part, without processes. They all have a conspicuously large vascular foramen on each side of a prominent ridge. A pair of smaller foramina for the centrum veins is seen in the floor of the neural canal. The ribs are single-headed, their sutures well indicated,

FIG. 7.— *T. bentonianum*. Sacrum, from above, one-fourth natural size.

though they, as also the neural arches, are firmly attached to the centrum.

Length of atlanto-axis	80 mm
Diameter of axis posteriorly	54
Lengths of vertebrae, as preserved	37, 37, 48, 50, 50, 50, 50
Transverse diameters of same	53, 75, 75, 75, 83, 86

There are fifteen dorsal vertebrae preserved in the type specimen, none of which is complete, though the preserved parts indicate well their structure. Two united anterior thoracic vertebrae have each a length of 63^{mm} and a width of 85^{mm}. The transverse processes, arising low down, are stout, and the zygapophyses are large and stout. The underside of the centrum is gently concave, and has the usual

two vascular foramina, but they are small, and the ridge between them is obsolete. Posteriorly the centra become more nearly circular in outline, and the articular surfaces are nearly flat, the under border also nearly straight. The transverse processes here are more slender and are directed more obliquely upward. The zygapophyses are smaller and weaker.

Lengths	63, 63, 66, 70, 72, 72, 72, 72
Widths	85, 85, 97, 97, 97, 97, 97, 97
Heights of centra	86, 86, ? 97, 97, 97

Sacrum.—The structure of the sacrum is so well shown in the figures (figs. 7, 8) that a detailed description is unnecessary. The specimen is of especial interest as for the first time giving a complete knowledge of this part of the vertebral column in the plesiosaurs. Three vertebrae, it is seen, take part in the structure of the sacrum. A fourth in front, probably, as in *Pantosaurus*, has its sacral rib arising from the centrum in part and participating in the support of the ilium, but if so it was not preserved with the remainder of this skeleton. The two posterior vertebrae are co-ossified, the front one not. The anterior sacral rib was connected with the ilium by ligamentous union, a rugosity for which is usually observed at a little distance from the extremity of the ilium.

FIG. 8.—T. *bentonianum.* Sacrum from right side, one-fourth natural size.

The opinion has been expressed at various times that the plesiosaurs are related to the turtles because of the position of the ilia, directed as they are downward and forward. But I see no necessity for such an explanation of the resemblances here. The hind limbs in the turtles, as in the plesiosaurs, are used chiefly as propelling organs. The strain upon the ilium at the acetabulum would be antero-posterior, inclining the ilium forward. While the union with

ilium was a strong one, as is shown by the large size of the sacral ribs, it was clearly a yielding, ligamentous one.

Pectoral girdle (Fig. 3).—The pectoral girdle lacks most of the scapulae, save their clavicular ends, the outer angles of the clavicles, and a portion of the coracoids. Otherwise it is in a remarkably undistorted and natural condition.

Scapula.—In the type specimen the extremity of the ventral process is preserved in relation with the clavicles and interclavicle. It is a flat, thin plate, underlapping the clavicle, meeting suturally the clavo-coracoid process for a short distance, with its distal mesial border slightly thickened, angularly, for cartilage. The outer part of the plate is missing on both sides; it doubtless covered the clavicle to the free border.

Interclavicle.—The interclavicle is a large, triangular bone, with a deep posterior emargination, and is strongly convex on its lower surface from side to side. As seen from below, there is an elongate process, with a small, narrow, slit-like emargination in the middle in front. The visible border widens gradually for a considerable distance, and then turns outward sinuously to the hind angle. The real border is underlapped in front by the clavicles, as is indicated by the interclavicle of *T. anonymum* (*Field Mus. Publ.*, No. 73, p. 44, f. 9), continuing in front of the anterior end of the clavicles as a seeming continuation of their borders. The posterior border is thin and squamous, directed outwardly nearly transversely on each side of the interclavicular foramen. It sends a pointed process back on each side a third of the distance of the foramen, apparently, though scarcely forming a part of the border of that opening. In the middle there is a deep emargination forming a fossa continuing the foramen anteriorly, its roof filled in by a thin bone suturally underlapping the interclavicle.

Clavicles.—The clavicles are elongate, triangular bones, in position and shape resembling those of *T. osborni*. The outer angle of each is lost in the specimen. On either side of the interclavicle they are visible in front. The posterior outer border is also concave, beginning in the angular depression lodged in the depression of the underside of the clavo-coracoid processes. Just in front of these processes is the arge interclavicular foramen, ovate in shape, rounded in front and

acute behind. The front border of the foramen is evidently formed by the clavicles, but no median suture is visible.

Coracoids.—The right coracoid has the proximal part of the scapula in position. The two coracoids formed a deep trough, with the anterior processes directed somewhat ventrad. The intergelenoid bar is very much thickened, with a deep concavity transversely above. The left bone shows, on the posterior side near the thickening, the margin of a foramen, as has been observed in species of *Polycotylus* and in *T. osborni*. It may be the real coracoid foramen. The glenoid fossa looks directly outward in the articulated position. The clavo-coracoid processes are elongate and flattened, the thickened inner border beveled obliquely for symphysial union. The sutural surface for the interclavicle extends on the visceral surface about two-fifths of the distance to the base of the process. The anterior ends are slightly thickened for cartilaginous attachment.

The united bones of the girdle are, as stated, in this specimen quite normal in position and shape, and, so far as they are preserved are in the relations of life. The under margin of the interclavicle turns upward at an angle of about ten degrees from the plane of the coracoids, and the girdle is very convex transversely on the under side. A much wider knowledge of the structure of the pectoral girdle in the older reptiles since the publication of my first paper convinces me of the correctness of the determination of the elements. The clavicles and interclavicle are assuredly the same elements, and not unlike those of the older reptiles. The ventral process is, furthermore, I am confident, not the united procoracoid, but merely a prolongation of the scapula, corresponding to the 'acromion' of such reptiles as *Dicynodon*, etc. What has become of the procoracoid we cannot positively say, but I believe that, as Seeley has suggested, it is represented by the portion of the coracoid in front of the foramina described. If this supposition be true, the immense size of the coracoid is chiefly due to the development of the procoracoid. And it is not unreasonable to suppose that such a development might have occurred; the two bones always meet normally in the middle, and do yet in the Monotremata, and the same propelling function of the fore limbs would tend to develop strongly these parts, as it has the pubes of the pelvic girdle. Furthermore, in the Elasmosauridae, the posterior

parts of the coracoids are broadly separated, their early, normal condition. The interclavicular foramen is a relatively late development, reaching its highest extreme in this genus and *Polycotylus*. Such a foramen, imperfectly understood, occurs in *Muraenosaurus*, and in a species described by me from the lower Cretaceous of Kansas provisionally, but incorrectly referred to *Plesiosaurus*.[1] What its function was it is difficult to say, if it had any, and its well-formed and thickened borders suggest that it did have some function.

Length of interclavicle	224 mm
Expanse of interclavicle	166
Width of foramen	33
Length of foramen	90
Length of clavicles	410

Pelvis.—The pelvis, though incomplete, has no distortion or malformation. The larger part of each ischium is present, the two united in the median line, and the left one has the ilium attached. The right ilium is quite perfect. Its upper extremity is flattened from within outward, and has a roughened surface on the inner side near the end for ligamentous attachment to the first of the sacral ribs. Below, the shaft is thicker, at its middle forming nearly a circle in cross-section. The lower extremity is thickened, club-shaped, with a large, flat, articular surface, broadly oval in shape, the anterior broad part looking more directly downward for the acetabulum; the posterior, more obliquely placed, smaller and subtriangular in shape, for articulation with the ischium. The anterior border of the bone is concave, with a slight convexity above, and a strong convexity at the lower end. The posterior border is convex except at the lower part, where there is a concavity.

Length of ilium	323 mm
Diameters of shaft at middle	37, 53
Greatest diameter of lower extremity	82
Antero-posterior diameter of lower extremity	100

Ischia.—The ischia are shaped very much as in *T. osborni*, that is, elongate and narrow, a characteristic of the group. Both ischia are present, attached to each other, and, as already stated, to the pubes.

[1] *Loc. cit.*, p. 44, Fig. 11.

The left ischium also is united with its ilium. The bones are somewhat concave longitudinally above, and considerably so from side to side. The blade is thin. In front view, when articulated, the interacetabular thickening lies nearly horizontal, with the acetabular thickening lying above the transverse plate so that the acetabulum looks upward and outward. Back of the thickening, the downward curvature of the thinned part leaves an obtuse keel in the middle.

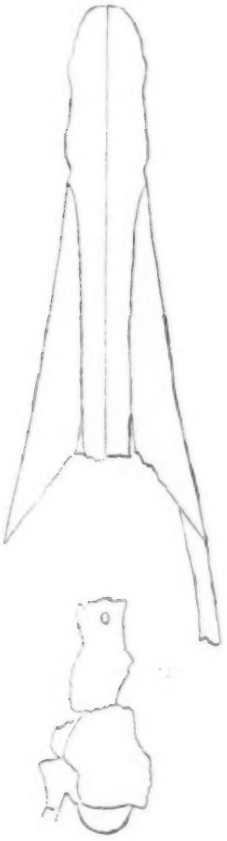
Pubes.—The pubes are incomplete, but their outline cannot differ materially from that of *T. osborni*. The right pubis is firmly attached to the ischium in its natural position. The sutural border is but little more than half the length of the acetabular border; thence to the symphysial angle the curve is smoothly and deeply concave, the immediate border for the most part somewhat thinned, though the bone is thickened a little in front of it. The external border, thinner, is not evenly concave as in *T. osborni*, but is sinuous, with a convexity in the middle of the concavity. The anterior external angle is somewhat thickened and rounded. Of the thin anterior border a part has been lost. The symphysial border is squarely truncated, showing a horizontal union. The upper surface of the bone is strongly concave, the external angle turned upward at about thirty degrees from the horizontal part. As is indicated in the pelvis of *T. osborni*, the whole bone turns downward distinctly from the plane of the ischium.

Width of pubes, from side to side, as articulated	682 mm
Antero-posterior extent of pubis, approximated	403
Width of neck of pubis	157
Length of symphysis	255
Length of ischium	600
Expanse of ischia	630

Paddles.—Parts of three paddles are preserved, one of them nearly complete, though, unfortunately there is no complete propodial among the material.

The proximal articular surface of the humerus forms nearly a hemisphere, the pitted cartilaginous surface limited sharply by a distinct rim. The tuberosity stands out prominently on the dorsal side, its top only has a distinctly limited cartilaginous surface connected with that of the head. The shaft below the head is somewhat oval. The distal extremity of one propodial has the epi-, meso-, and

metapodials and the first row of the phalanges attached, except that the epipodial supernumeraries are absent. Another, similarly united proximal series of the smaller bones has the first epipodial supernumerary in place, and there is possibly a place for a second one,



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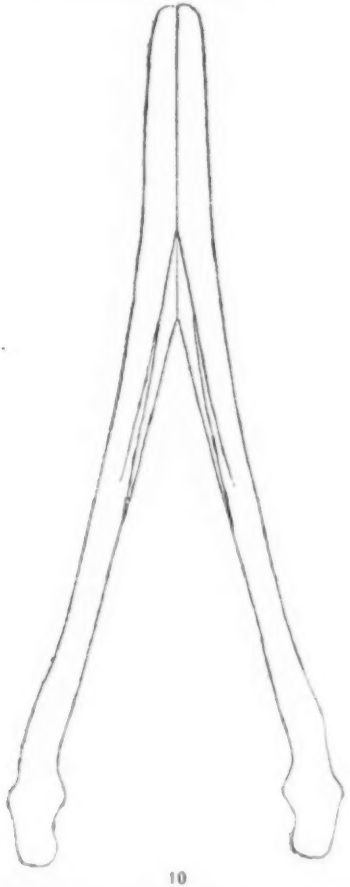

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FIG. 9.— *Trinacromerum anonymum* Williston. Outline of anterior part of skull, from above; a little less than one-sixth natural size.

FIG. 10.— *T. anonymum*. Outline of mandibles from below; a little less than one-sixth natural size.

as in *Polycotylus*. The generic name is derived from the belief that there were but three bones in the epipodial row. Beyond these connected series of bones there is another, and still a third includes the extreme tip of the paddle. In the first digit there are actually preserved ten phalanges, in the second twelve, and in the third fourteen—this last is the longest. The second digit could not have had less than fifteen and the third twenty. The three distal phalanges of the first digit seem to have been imperfectly ossified, and are closely related to, if not co-ossified with, the second digit. So, also, the distal four phalanges of the fifth digit are united, and are closely applied to the fourth digit, as are also the terminal three or four of the second with the third. The terminal phalanges of the third and fourth digits are flattened at the end, almost ungulate. The paddles are remarkably long and slender.

Trinacromerum anonymum Williston

A specimen in the Yale Museum (No. 1129), collected in 1873 by the late Mr. Joseph Savage from the Benton Cretaceous of Kansas "three miles south of the Solomon," is clearly identical with the species which I figured and partially described under the provisional name *Trinacromerum anonymum*, the type specimen collected by the late Professor Mudge from nearly the same locality and doubtless the same horizon in the Upper Benton. The species differs from the type species in its much smaller size, less slender skull, the different shape of the interclavicle and of the propodial bone. The Yale specimen must originally have been an excellent one, comprising the skull and vertebral column and portions of the paddles, but like so many of the specimens of those early days it suffered in its collection. The skull (figs. 9, 10), so far as it is preserved, bears a strong resemblance to *T. osborni*, but the attenuated portion of the face is shorter and the symphysis of the mandibles much shorter. The undersurface of the parietals with their attachments is clearly shown, and a little in front the opening into the deep median sinus or canal leading to the pineal foramen 50^{mm} in advance is clearly seen. Two tongue-like projections lie close together, projecting apparently as far forward as the end of the projection, the under surface with longitudinal striae like those of the upper surface. On each side there is a broad deep

fissure for the attachment of the so-called prefrontal or "frontal," but there is not the slightest indication of a suture either above or

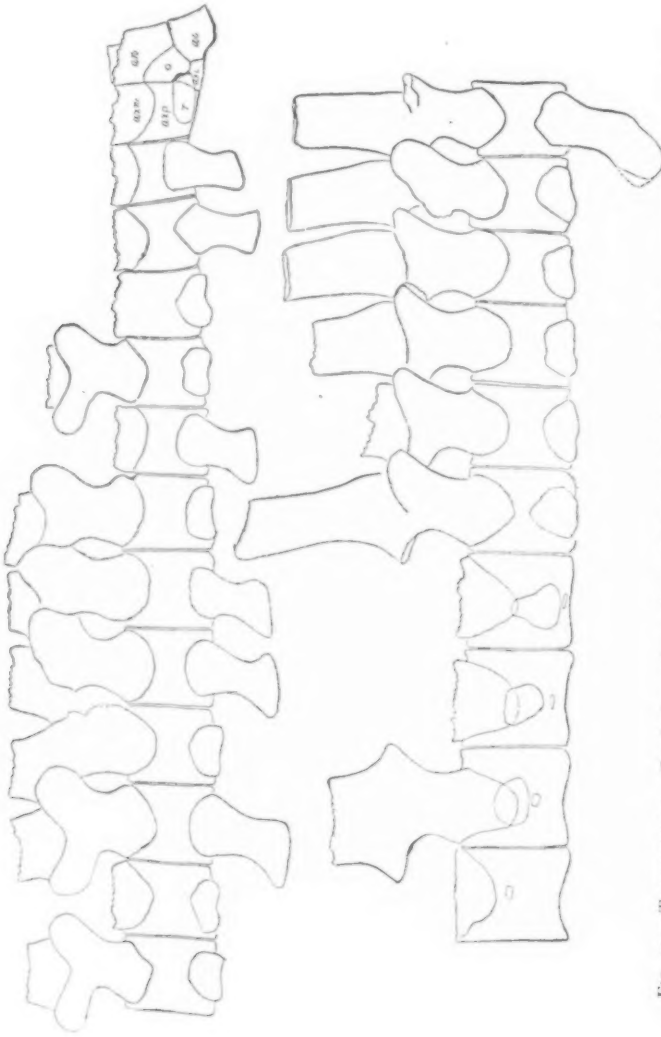

FIG. 11 — *T. anonymum*. Cervical vertebrae, three-eighths natural size. ai, atlantal intercentrum; axi, axial intercentrum; axp, axial pleurocentrum; o, odontoid (atlantal pleurocentrum); r, place of rib attachment.

below, separating this anterior projection, which goes forward to meet the premaxilla, from the true parietal.

The supraoccipitals are shaped nearly as *T. osborni*, though they may meet for a short distance above.

Twenty-three cervicals in a continuous series are present, their processes for the most part lost. As this is the first absolutely positive

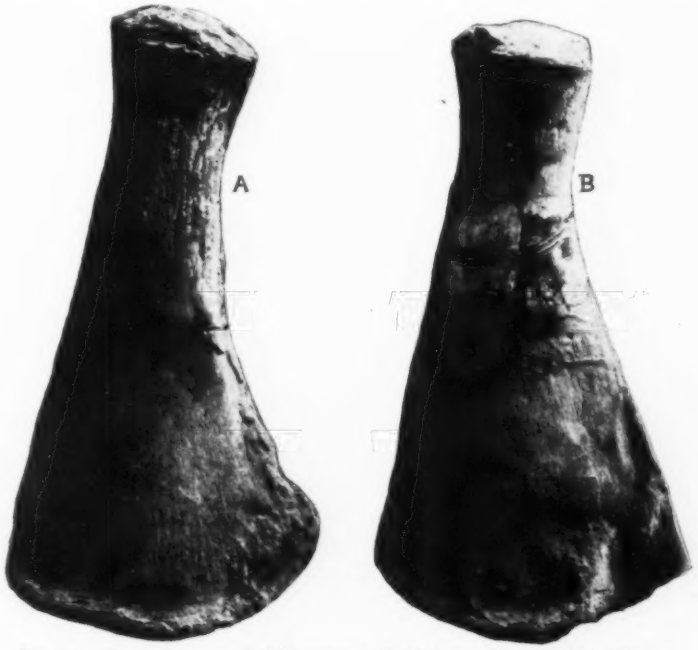

FIG. 12.— *T. anonymum*. A, left humerus; B, left femur, No. 1129 Yale Museum.

determination of the number of cervical vertebrae in this genus, I give careful outline figures of the series (fig. 11). The centrum of the third vertebra measures 23^{mm} in length, 32 in height, and 40 in width. The tenth vertebra has for its corresponding measurements 32, 34, 42; the twentieth, 32, 40, 58. The zygapophyses are heavy and large, placed nearly at right angles with each other, and are nearly plane. The twenty-fourth has the diapophyses wholly on the

arch, and is, hence, a true dorsal vertebra, leaving twenty as the number of true cervicals, and three pectorals. The characteristic structure of the cervical and dorsal vertebrae of *Polycotylus latipinnis* is shown in fig. 13.

Twenty-three presacral centra follow. They are all depressed from pressure. The largest measures 42^{mm} in length and the series 1,300^{mm}. The length of the neck is 700^{mm}, that of the skull 700^{mm}, giving a total length of the animal in life as about eleven feet, or a little greater than that of the type specimen of *T. Osborni*.

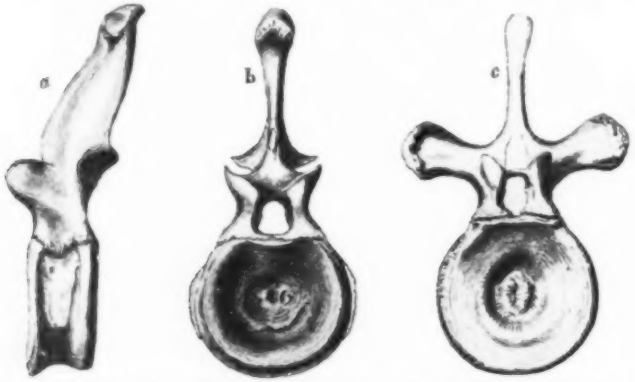

FIG. 13.—*Polycotylus latipinnis*. a, twenty-sixth (last) cervical vertebra from the side; b, the same vertebra, from in front; c, dorsal vertebra (forty-fourth of series) from in front. All one-fourth natural size.

Trinacromerum latimanus, n. sp.

Among the collections of the University of Chicago from the Hailey Shales of the Upper Benton of Wyoming, are parts of two individuals which I refer to an undescribed species of *Trinacromerum* chiefly because of the absence of the second supernumerary epipodial in the limbs and the character of the vertebrae. One of these specimens has the posterior part of the skull, a number of vertebrae and portions of the limbs; the other, which may be taken as the type, is an isolated humerus in perfect condition, collected by Mr. Roy Moodie (fig. 15). From the humeri of *T. bentonianum* and *T. anonymum* it differs conspicuously in its greater expansion distally. From the humerus of *Polycotylus latipinnis*, which I here figure for the first

time (fig. 14), it differs in the absence of the fourth epipodial, the greater concavity of the ulnar border, the convexity of the distal radial border, etc.

FIG. 14.— *P. latipinnis.* Left humerus, dorsal side, three-sevenths natural size.

Length	351 mm
Least diameter of shaft	87
Greatest width	250

The next paper of this series will be devoted to a discussion of the Jurassic species.

FIG. 15.— *Trinacromerum latimanus*. Left humerus, dorsal side, three-sevenths natural size.

Family POLYCOTYLIDAE Cope

Skull with long facial rostrum and thin, high parietal crest. Supraoccipital bones separated. Palate with large interpterygoidal vacuity, the pterygoids articulating with vomers, and meeting in the middle line posteriorly; no palatine foramina. Neck but little longer than head, the vertebrae all short; ribs single headed. Coracoids meeting throughout in symphysis, with long clavicular processes articulating with clavicles and scapulae, the interclavicle present; a large interclavicular foramen; ischia elongate. Three or four epipodial bones, all broader than long. Colorado Cretaceous, North America.

Polycotylus

Cope, *Proc. Amer. Phil. Soc.*, XI, 117, 1869; Williston, *Amer. Journ. Sci.*, XXI, 233, March, 1906.

P.) latipinnis Cope, *loc. cit.; Ext. Batrachia*, etc., 36, pl. 1, ff. 1–12; *An. Rep.*, U. S. Geol. Surv., 1871, 388; *ibid.*, 1872, 320, 335; *Bull.*, U. S. Geol. Surv. Terr., 27, 1874; *Cretac. Vert.*, 45, 72, 255, pls. I, VII, ff. 7, 7*a*; Leidy, *Ext. Vert. Fauna*, 279; Williston, *Field Mus. Publ.*, No. 73, p. 67, pl. XXI; *Amer. Journ. Sci.*, 2, 234, pl. III, Niobrara Cretaceous, Kansas.

P.) dolichopus Williston, *Amer. Journ. Sci.*, XXI, 235, pl. III, f. 2; Niobrara Cretaceous, Kansas and Wyoming.

Trinacromerum

Cragin, *Amer. Geologist*, December, 1888, p. 404; September, 1891, p. 171; Williston, *Amer. Journ. Sci.*, XXI, 236; *Dolichorhynchops* Williston, *Kans. Univ. Sci. Bull.*, No. 9, p. 141, September, 1902; *Field Mus. Publ.*, etc.

T.) bentonianum Cragin, *loc. cit.* Fencepost horizon of Benton Cretaceous Downs, Kansas.

T.) osborni Williston, *loc. cit.; Amer. Journ. Sci.*, XXI, 234; *Field Mus. Publ.*, No. 73, pp. 1–51, pls. I–XVII (*Dolichorhynchops*). Niobrara Cretaceous, Kansas.

T.) anonymum Williston, *loc. cit.*, p. 45, pl. XVIII. Upper Benton Cretaceous, Kansas.

T.) latimanus Williston, *antea*.—Hailey Shales, Upper Benton, Wyoming.

Piratosaurus

Leidy, *Cretac. Rept. N. Amer.*, p. 29, 1865.

P.) plicatus Leidy, *loc. cit.*, pl. XIX, f. 8. Cretaceous, Manitoba.

As has been suggested, this genus is perhaps identical with *Polycotylus* or *Trinacromerum*, in which case the name must take priority. If so, the determination cannot be made with certainty until such time as more complete specimens from the type, locality, and horizon have been studied.

The above species are all that are known belonging to the group. It is possible that other forms from the Fort Pierre may eventually be found, perhaps some have been described under other names. I may add here that the type of *Nothosaurops occiduus* Leidy is unquestionably a *Champsosaurus* Cope, as was suggested by Zittel, and that name should take precedence.

LIST OF DESCRIBED NORTH AMERICAN PLESIOSAURS

JURASSIC (BAPTANODON BEDS)

Plesiosaurus shirleyensis Knight.—Wyoming.
Pantosaurus striatus Marsh.—Wyoming.
Megalneusaurus rex Knight.—Wyoming.
Cimoliasaurus laramiensis Knight.—Wyoming.

LOWER CRETACEOUS (COMANCHE)

Plesiosaurus mudgei Cragin.—Kansas.
Plesiosaurus gouldi Williston.—Kansas.

BENTON CRETACEOUS

Trinacromerum bentonianum Cragin.—Upper, Kansas.
Trinacromerum anonymum Williston.—Upper, Kansas.
Trinacromerum latimanus Williston.—Upper, Wyoming.
Brachauchenius lucasii Williston.—Middle or Lower, Kansas, Texas.
Elasmosaurus, n. sp. Williston.—Middle, Kansas.

NIOBRARA CRETACEOUS

Elasmosaurus snowii Williston.—Middle, Kansas.
Elasmosaurus serpentinus Cope.—Nebraska, Wyoming.
Elasmosaurus marshii Williston.—Middle, Kansas.
Elasmosaurus ischiadicus Williston.—Upper, Kansas.
Elasmosaurus nobilis Williston.—Basal, Kansas.
Elasmosaurus sternbergi Williston.—Middle, Kansas.
Polycotylus latipinnis Cope.—Kansas.
Polycotylus dolichopus Williston.—Kansas, Wyoming.

FORT PIERRE CRETACEOUS

Plesiosaurus gulo Cope.—Kansas.
Elasmosaurus platyurus Cope.—Basal, Kansas.
Elasmosaurus intermedius Cope.—South Dakota.
Uronaules cetiformis Cope.—Montana.
Ophrosaurus pauciporus Cope.—Fox Hills, New Mexico.
Piptomerus megaloporus Cope.—Fox Hills, New Mexico.
Piptomerus microporus Cope.—Fox Hills, New Mexico.
Piptomerus hexagonus Cope.—Fox Hills, New Mexico.
Embaphias circulosus Cope.—South Dakota.

CRETACEOUS OF NEW JERSEY AND THE SOUTH

Plesiosaurus brevifemur Cope.—Greensand No. 5, New Jersey.
Cimoliasaurus magnus Leidy.—Greensand No. 5, New Jersey.
Discosaurus planior Leidy.—Mississippi, New Jersey.
Brimosaurus grandis Leidy.—Arkansas.
Elasmosaurus orientalis Cope.—New Jersey.
Taphrosaurus lockwoodi Cope.—No. 1, New Jersey.

OF DOUBTFUL RELATIONS AND HORIZON

Oligosimus primaevus Leidy.—Green River, Wyoming.
Piratosaurus plicatus Leidy.—Cretaceous.

THE LOCALITIES AND HORIZONS OF PERMIAN VERTEBRATE FOSSILS IN TEXAS

W. F. CUMMINS

The vertebrate fossils from the Permian formation in Texas described by Professor E. D. Cope were collected by myself and others before any stratigraphic work had been done in the part of the state in which that formation occurs, and the only thing that could be done by the collector was to give the locality from which the specimen was taken. Whether the different localities were of the same horizon or whether they were entirely different beds was not known, and consequently could not be given.

At a subsequent period, as a member of the Texas Geological Survey, I made a thorough examination of the country and complete stratigraphic sections across the entire Permian area. These sections were published in the *Second Annual Report* of the Survey.

After the stratigraphic work had been done, I took up, with Professor Cope, the work of giving the horizon of each of his described forms and the study of the development of the forms of life. Unfortunately, before the completion of this work the death of Professor Cope occurred, and his collection passed into other hands and the paper was not prepared. Later, I asked Professor Osborne, into whose hands most of Professor Cope's Permian fossils had gone, to send me the localities as given on the labels with the fossils collected from Texas. The request was referred to Professor E. C. Case, who very kindly furnished me with such facts as the labels disclosed.

More recently, Dr. W. D. Matthews, of the American Museum of Natural History, New York, sent me the card list and the original lists sent to Professor Cope by the collectors, together with the original correspondence relating to the collections.

From these sources I have been enabled to give the localities of most of the vertebrate fossils collected.

After these fossils had been collected, Dr. C. A. White, of the United States Geological Survey, came to Texas, and together we

visited the Permian beds and made a collection of the invertebrate fossils. Part of these occurred at some of the same localities as those from which Cope's vertebrate forms were taken. These invertebrates were afterward described by Dr. White (*Amer. Nat.*, 1889, p. 128, and United States Geological Survey, *Bull. No. 77*).

Subsequently further collections of invertebrate fossils were made by myself and other members of the Texas Survey. The cephalopods were placed in the hands of Professor Alpheus Hyatt for determination and description. His reports were published as parts of the *Second* and *Fourth Annual Reports* of the Texas Geological Survey.

The fossil flora was sent to Professors Fontaine and I. C. White for their determination. A paper was published by them (*Bulletin of the Geological Society of America*, Vol. III, pp. 217, 218), giving the results of their study.

It is the purpose of this paper to describe more accurately the various localities from which the fossils were taken, to indicate their stratigraphic relation to the general section, and bring together a list of the vertebrate forms[1] so far described from each locality, as nearly as it is possible to give it from existing data.

THE GENERAL SECTION

The Permian deposits were described and separated into divisions in the several reports of the Geological Survey of Texas. As a whole, the formation comprises a series of sands and clays with interbedded sandstones, limestones, and gypsum, lying conformably and with a gentle westward dip upon the Coal Measures to the east and stretching to the foot of the Staked Plains on the west. Three divisions are recognized, the earliest and most easterly being the Wichita, followed successively by the Clear Fork and Double Mountain.

The Wichita division comprises a series of sandstones, sandy shales, clays, and conglomerate, which passes gradually to the southward into sandstones, clays, and limestone. In the earlier reports, there being no apparent stratigraphic break between it and the underlying Coal Measures and its materials being quite different from the Wichita, these beds in the southern part of this field were

[1] The lists sent me include batrachia and reptilia only. The fish will, therefore, not be included in this.

called the Albany beds and were assigned to the Coal Measures. Subsequent study, however (*Texas Academy of Science Trans.*, Vol. II, pp. 93–98), disclosed the fact that the beds were stratigraphically continuous with the Wichita, being simply deposits in deeper waters, and in all subsequent publications they have been included in the Wichita, referred to the Permian, and the name Albany dropped.

The Clear Fork beds are composed of bedded limestone, magnesian and earthy, followed by clays, limestones, and shales, and are more sandy toward the top.

The Double Mountain beds comprise sandstones, sandy shales, earthy limestone, clays, and thick beds of gypsum.

For details of the sections reference is made to the *Second Annual Report* of the Geological Survey of Texas, pp. 402 ff.

So far as our collections show, the first vertebrate fossils are found in beds which are a little below the middle of the Wichita division. The beds below these, while not differing materially in character, are possibly the representatives of the transition beds of the territory north, as Adams suggests,[1] but from the evidence here given it is plain that such a reference cannot apply to any beds west of Onion Creek.

In describing these localities I have begun with those nearest the base and have given them as nearly in stratigraphic sequence as our present knowledge will permit.

I have tried to give all localities at which we made collections of vertebrate fossils, whether the forms have been identified or not.

LOCALITIES OF WICHITA DIVISION

Onion Creek.—A few miles east of Archer City there is a small tributary on the south side of the Little Wichita River called Onion Creek. Near the mouth of this stream, the first fossil vertebrate of the Texas Permian was found by Professor Jacob Boll, who afterwards sent it to Professor Cope.

Cottonwood Creek.—This creek is about ten miles south of Archer City and is a tributary of the South Fork of Little Wichita.

Fire Place.—This is on the west side of the South Fork of the Little Wichita about six miles south of Archer City. It is one of Boll's localities.

[1] *Bulletin of the Geological Society of America*, Vol. XIV, pp. 191–200.

Elm Creek.—A tributary of the South Fork of the Little Wichita, about twelve miles southwest of Archer City. Collections were made on east side of creek.

Fossils: *Dimetrodon gigas, D. dollovianus*

Post Oak Pens.—This locality is south of the head of Kickapoo Creek, on the head of the South Fork of the Little Wichita River about fifteen miles southwest of Archer City. From here I took quite a collection of the teeth of fishes. The horizon is below that of Tit Mountain, or Corn Hill.

Copper Mines.—About one-half mile east of the copper mines there is a small area of "bad lands" at which place I collected some fragments of vertebrates and many teeth. This is about the same horizon as Post Oak Pens. This locality is four miles west of Archer City.

Long Creek.—This creek runs into the Little Wichita on the north side, just a little west of the copper mines.

Fossils: *Empedias alatus, Dimetrodon incisivus, Naosaurus cruciger*

Mount Barry.—This is a prominent hill in the valley of the Big Wichita about ten miles west of Wichita Falls. This is about the middle of the Wichita division.

Fossils: *Empedias alatus*

Briar Creek.—A small branch running into the North Fork from the south side, a few miles west of Kickapoo Creek.

Fossils: *Naosaurus cruciger*

Slippery Creek.—This is a small creek that runs into the North Fork of the Little Wichita from the north side almost directly south of the town of Dundee, and a little above the mouth of Briar Creek on the south side.

Fossils: *Trimerorhachis sp., Eryops sp., Dimetrodon incisivus, D. giganhomogenes, Ctenosaurus sp.*

Cox's Camp.—A few miles east of the mouth of Godwin Creek, when the collections for Cope were being made, the Harrold Brothers had a line riders' camp, known as Cox's camp. Just east of that camp, on the north side of the Little Wichita River, there is a small area of "bad lands." At this place one of the best-preserved fossils in the entire Cope collection was found.

Fossils: *Trimerorhachis sp., Eryops sp., Empedias sp.*

Headquarters.—The first headquarters established by Harrold Brothers for their extensive ranch was on the north side of the North Fork of the Little Wichita River, a mile or two from the mouth of Kickapoo Creek, a tributary of the North Fork from the south side. Some of Cope's fossils were taken from this locality.

Corn Hill.—Corn Hill, formerly called Tit Mountain, is No. 31 of our section and is about a mile north of Dundee, and is higher in the formation than the beds at Mount Barry.

Fossils: *Trimerorhachis bilobatus, T. sp., Dimetrodon incisivus, D. macrospondylus, D. longiramus*

Godwin's Creek.—A tributary of the Little Wichita River from the south side. It runs from a southwestward direction nearly on the strike of the beds, having its source in the limestone hills of the Clear Fork Division ten miles away. From its mouth to the crossing of the road from Archer City to Seymour there is quite a body of "bad lands." Several specimens of Cope's fossils were taken from this place. About one-half mile east of the crossing of the Archer and Seymour road is Dr. C. A. White's Godwin Creek invertebrate locality. About two miles up the creek, on the south side above the road crossing, is the locality from which the fossil flora was taken described by Dr. I. C. White as coming from Godwin's Creek. The Antelope locality in the same paper is Carboniferous.

Fossils: *Diadectis sp., Empedias fissus, Dimetrodon platycentrus*

Hackberry Creek.—This is a small tributary of the Little Wichita river, about three miles southeast of Fulda. It is one of Mr. Sternberg's localities.

Fossils: *Eryops sp., Diadectes sp.*

Deep Red Run.—There was at one time a small fort called Fort Auger on the north side of Red River about opposite where the town of Iowa Park is now located. There was a road leading from Fort Auger to Fort Sill. Near the crossing of Deep Red Creek by this old road is the locality at which I collected the vertebrates in Cope's collection labelled "Indian Territory." The horizon is about the same as that of Corn Hill.

Fossils: *Cricotus hypantricus, Dimetrodon gigas, D. macrospondylus, D. dollovianus, D. platycentrus, Naosaurus cruciger*

Camp Creek.—About four miles west of Tit Mountain. It was named from the fact that Harrold Brothers had one of their line camps on it. At this place appears the first limestone as we go up the south side of the Big Wichita River. It is one of Dr. C. A. White's invertebrate localities.

Big Wichita.—Going west from Camp Creek and before reaching the locality designated as Military Crossing, there is an exposure of the beds given as No. 29 in the Section on p. 403, *Second Annual Report* Texas Geological Survey. This is not "Big Wichita" of Boll's collections. He used the term for various localities along the river.

Fossils: *Eryops sp., Clepsydrops leptocephalus, Theropleura retroversa*

Moonshine.—A small creek that runs into the Big Wichita River near the east line of Baylor County has the name of Moonshine. At this place I found a few vertebrate fossils.

Fossils: *Chilonyx rapidens, Dimetrodon gigas*

Military Crossing.—Before there were any other roads through this country or crossings on the Big Wichita River, Maj. Van Dorn made a road from Fort Belknap to old Fort Radminski, at the western end of the Wichita Mountains near Otter Creek. This road crossed the north fork of the Little Wichita River near its head. It crossed the Big Wichita River at the eastern foot of the hills a little west of north of Fulda and near where, at a later date, the west line of the "99" pasture fence was built. This crossing has been abandoned for a great number of years and the locality must not be confused with the old cattle trail made several years later, nor the county road made between the two crossings at a still later date. About one and a half miles north of this crossing, on the Big Wichita River, is a small dry creek. On the north side of that creek, about one-fourth of a mile from the old road, is the locality known as Military Crossing. This horizon is near the top of the Wichita Division. This locality furnished the greater number of the invertebrates collected by Dr. White.

In addition to the forms given under the above localities, the following were collected within the area occupied by the Wichita division, but the localities are not given closely enough to permit their being referred to any definite horizon: *Zatrachys seratus, Eryops*

megacephalus, Cricotus crassidiscus, Diadectes phaseolinus, D. latibuccatus, Empedias molaris, Pariotichus brachyops, Pantylus cordatus, Clepsydrops natalis, C. limbatus, Dimetrodon semiradicatus, Metamosaurus josssatus, Paleosaurus uniformis, Embolobusf ritillus

So far as known none of these species occur above the Wichita beds.

As has been stated, the continuations of these beds to the south comprise deposits of deeper water and carry a large invertebrate fauna. The details of the stratigraphy and fossils of this division on the Colorado river are given by Dr. Drake in the *Fourth Ann. Rep. Geol. Sur. Tex.*, pp. 421 ff.

Ballinger and North of Abilene, the localities of Professor Hyatt's cephalopods, are well known. They are the same horizon as that of Military Crossing.

LOCALITIES OF CLEAR FORK DIVISION

Coffee Creek.—In the northeastern corner of Baylor County, about four miles west of Military Crossing, a small stream, generally dry, runs into the Big Wichita River from the north. The old cattle trail crossed the Big Wichita River about three miles above the mouth of Coffee Creek. As will be seen, this was a very prolific locality for collectors:

Fossils: *Diplocaulus magnicornis, D. limbatus, D. sp., Trimerorhachis mesops, Zatrachys micropthalmus, Eryops sp., Acheloma cumminsi, Anisodexis imbrocarius, Diadectes phaseolinus, D. sp., Pariotichus aguti, Captorhinus angusticeps, Pantylus tryptychus, P. coicodus, Labradosaurus hamatus, L. sp., Dimetrodon gigas, D. dollovianus, Naosaurus claviger, N. cruciger, N. macrodus, Edaphosaurus pagonias*

Boneyard.—The old cattle trail from the south to the north, at the time the Cope collections were made, crossed the Big Wichita River about two and a half miles above Coffee Creek. Just east of that road, on the north side of the river, is an area of "bad lands." At this place there were a great number of fragments of vertebrates, so much so that Mr. Sternberg gave it the name of "Boneyard" and so labelled many of the fossils collected by him.

Fossils: *Diadectes sp., Empedias sp.*

Beaver Creek.—At the crossing on Beaver Creek of the old cattle trail mentioned elsewhere as crossing the Big Wichita River west of Coffee Creek is another locality at which I collected fossils for Cope. Boll's locality "Beaver Creek" was at its mouth and in the Wichita Beds.

Brushy Creek.—Six miles northwest of Seymour is the head of Brushy Creek, which runs into the Big Wichita River on the south side.

Fossils: *Eryops sp., Diadectes sp.*

Indian Creek.—This creek runs into the Big Wichita River on the north side nearly opposite the mouth of Brushy Creek.

Fossils: *Diplocaulus sp., Trimerorhachis conangulus, Eryops sp., Diadectes sp., Pariotichus isolomus, Isodectes megalops, Dimetrodon giganhomogenes, Naosaurus claviger*

Gray Creek.—In same vicinity, south of river.

Fossils: *Otocoelus testudineus, Conodectes favosus*

Crooked Creek and Hog Creek.—Same vicinity, south of river.

Fossils: *Diplocaulus sp., Labidosaurus sp., Naosaurus claviger*

Stamford.—While connected with the Texas Geological Survey, I collected some vertebrates from the Clear Fork beds in Haskell County, Texas, near Otey's Creek, not far from the present town of Stamford (*Second Ann. Rept. Tex. Geol. Surv.*, p. 405.)

Other forms described from the Clear Fork division but not localized are: *Zatrachys conchigerus, Dissorhopus multicinctus, Bolbodon tenuitectus, Pariotichus isolomus, Hypopnous squaliceps, Otocoelus mimeticus*

The forms described from this region which we cannot certainly assign to either division comprise: *Trimerorhachis insignis, Zatrachys apicalis, Eryops erythroliticus, E. jerricolus, E. reticulatus Diadectes sideroplicus, D. biculminatus, Helodectes pandius, Pariotichus ordinatus, P. incisivus*

LOCALITIES OF DOUBLE MOUNTAIN DIVISION

Kiowa Peak.—A few years ago I procured a sandstone slab with impressions of tracks of a reptile, which is now in my collection at Dallas, Texas, but no attempt has been made to identify the animal making them. This slab was procured from a gulch a few miles

south of Kiowa Peak in Stonewall County, Texas (*Second Ann. Rept. Tex. Geol. Sur.* No. 15, p. 406). This would be about the base of the Double Mountain Division.

DISTRIBUTION

Of the eight genera of *Stegocephalia* only four, *Trimerorhachis*, *Zatrachys*, *Eryops* and *Cricotus*, have been found in the Wichita. The first three, together with *Diplocaulus*, *Dissorhopus*, *Acheloma*, and *Anisodexis*, are found also in the Clear Fork, *Cricotus* alone being absent from the latter beds. In all cases, however, the species occurring in the two divisions are different.

Of the *Cotylosauria*, *Diadectes*, *Empedias*, *Pariotichus*, and *Pantylus* are common to both divisions, but only a single species, *Diadectes phaseolinus*, occurs in both. In all other cases the genera are represented by distinct species. *Chilonyx* and *Bolosaurus* are confined to the Wichita, while *Bolbodon*, *Isodectes*, *Hypopnous* and *Labidosaurus* appear only in the Clear Fork.

The *Chelydosauria* are found only in the Clear Fork.

The distribution of the *Pelycosauria* is equally distinctive. While three species of *Dimetrodon* and two of *Naosaurus* extend through both divisions, we have as characteristic genera of the Wichita, *Cleopsydrops*, *Ctenosaurus*, *Theropleura*, *Metamosaurus*, *Paleosaurus* and *Embolophorus* and of the Clear Fork *Edaphosaurus* only.

It is therefore evident that the divisions of Wichita and Clear Fork which were proposed at first on purely stratigraphic grounds are fully warranted and upheld by the fossils found in them. And it will be found when the invertebrate forms collected from these divisions on the Colorado shall have been studied that this separation is equally warranted there.

SOME FEATURES OF EROSION BY UNCONCENTRATED WASH

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Erosion without valleys appears frequently to be regarded as due to the absence of all initial inequalities which might tend toward concentration of the run-off. It should follow as a corollary (and this too seems quite as often to be tacitly accepted), that such erosion cannot of itself perform a great geologic task, for, in nature, conditions of absolute equality are rare. If exemption from valley-cutting is due to such an exceptional condition, the wonder is that any broad slopes remain and that valleys do not branch indefinitely. Yet the observation is common that in loose and homogeneous material, the head of a gully is a perfectly definite thing, and that while some large gullies do arise from the union of smaller ones, this subdivision in a headward direction is not carried to microscopic dimensions.

If a broad slope without valleys is possible only with a nice equality of rills, its existence must be highly precarious, but it must be recognized that for every dissecting land surface there is a degree of minuteness beyond which dissection will not go, and when this degree is reached the slopes are in no danger whatever of further dissection. The exact degree of minuteness of dissection (or what has sometimes been called the *texture* of the topography) depends on a number of factors not here discussed. The purpose of this paper is to point out and account for that limitation and to examine some of the topographic effects of erosion without valleys. It should be made clear that such erosion is not in the main dependent on equality of conditions, and that among rills or runnels on a broad hillside there is not always a tendency to grow larger, hence not always a contest for mastery or a struggle for existence.

Conditions assumed.—The simplest and typical case for the study of this principle is that of the plowed field or other surface of homogeneous material. A sod cover may temporarily hold its own against

channeling, even where steamlets are sufficiently concentrated to carry their loads and have some power to spare. Even here, however, the failure to cut channels may be due less to the actual withstanding of wear than to the retardation of currents and their continued subdivision, that is, the power which would result from concentration of the water is *prevented* rather than *withstood*. This case and all others which are complicated by the nature of the material or by special initial slopes are omitted from this discussion, which is concerned only with the simplest and most typical case of gradual concentration of run-off and its effects. If there is any categorical difference between the wash above the gully-head and that below, it must appear best where there is perfect freedom for either mode of activity to occur.

Loss of power due to subdivision of stream.—It is a well-recognized principle that the carrying power of a given flow of water is greater when concentrated into a single stream than when subdivided into several streams. Its application to deltas is familiar, in which case it might be shown that although the united stream were able to carry its entire load, a sufficient degree of subdivision into distributaries would bring about a condition in which no one of these could transport its sediment; in other words, while the volume of water and sediment are divided arithmetically, the power of the water decreases in a greater ratio.

The same principle applies equally well to the opposite case, that is, to the union of several streams into one. Applied to this case it may be stated thus: Given a stream whose power is more than necessary to carry its load; suppose this to be formed by the union of smaller streams, each of which in turn was similarly formed, and so on back to the origin of all in unconcentrated wash; previous to a certain degree of concentration, when all streams were below a certain size, all were overloaded and hence unable to cut definite channels. It is a commonplace observation that definite and continuous channels cannot be cut until a certain degree of concentration is reached; but the point here emphasized is that this condition may be and often is due to actual overloading of the primary streamlets with sediment.

Sudden change from overloaded to cutting condition.—There is

apparently a tacit assumption that the gully differs only in degree from the rill-mark, or what amounts to the same thing, that the behavior of the water in gully-making is the same in kind but differing in degree from the behavior of water in rills. The attendant assumption is that the change from the earlier condition to the later is gradual. A point to be emphasized is that the two conditions differ fundamentally, not in degree but in kind, and that the change from one to the other is sudden. It will be seen that this harmonizes with the common observation that heads of gullies in homogeneous unconsolidated material and having a simple history, are perfectly definite as to form and location.

All streamlets above the point where continuous valley-cutting begins, are here conceived of as overloaded, hence wandering, braiding, etc., according to well-known habits. Their union is, however, to some extent progressive, and when a certain stage is passed, the power is more than necessary for the load, and then definite, progressive down-cutting begins. It is unnecessary to show just how such down-cutting favors further concentration of rills at that point and therefore when once begun, goes on at an increasing rate. It may, however, be said that the progressive union of overloaded rills is to a large extent fortuitous.

Terms.—The characteristic suddenness of the change from the overloaded condition of the small streamlets to the cutting condition after a certain degree of concentration has been reached, makes it desirable that these conditions should be designated by distinctive names. No such distinctive names are in use, for the good reason that the distinctive character of the streamlets previous to this degree of concentration, seems not to be generally recognized. In the vast majority of cases the word "rill" seems to be applied to such cases, but no essential characteristic is implied by that term except smallness. In the absence of a more specific term, and for the purposes of this discussion, the word "rill" will be used to indicate such a streamlet in an overloaded condition, that is previous to the degree of concentration necessary to cut a gully. It is not necessary to specify the want of permanence since that is a necessary corollary. The condition succeeding that of the rill is equally without a distinctive term and there seems to be nothing to do but to use the word "gully stream'

for one in that condition, since the making of a gully is its characteristic function.

The whole area over which rills alone are formed may well be spoken of as subject to "unconcentrated wash." This term is necessarily relative, for even a drop of water represents a degree of concentration and there is no categorical distinction until the cutting stage is reached. The terms "sheet flood" and "sheet wash" are appropriate both in a descriptive and a technical sense for certain phenomena, generally in arid regions, where the run-off from torrential rains descends a slope in visible sheets. The same terms are misleading when applied to the ordinary phenomena of unconcentrated wash. The "sheet" in this latter case is rather a net work of constantly changing pattern.

Down-cutting by unconcentrated wash and "overloaded streams."—It will probably not be questioned that unconcentrated wash may and commonly (perhaps universally) does degrade that part of a slope which lies above gully-heads. If the assumption made above be correct, we then have the case of degradation being performed by currents which, according to our accepted terminology, are overloaded. It is difficult to deny that this is the case. If it seems to involve a contradiction of terms, it may be necessary to define an overloaded stream (if the term be retained) not as one which deposits at a certain place more than it removes but as one which behaves in a certain way with reference to its load. The main features of such behavior are the building of bars, the shifting of channels, subdivision and braiding, and above all, the inability of the streams to incise any one channel beneath the level upon which it wanders.

It would be a mistake to assume that all streams which build bars, anastomose, shift their channels and "braid" are of necessity aggrading their valleys or even that they are not degrading them. The relations between these phenomena of "overloaded streams" on the one hand and aggradation on the other is not so simple as that. It may safely be assumed however that some of the conditions which favor anastomosing, etc., are also favorable to aggradation. The classical example of an "overloaded stream" (the Platte) is quite probably aggrading its valley at the present time in that part where the phenomena listed above are most pronounced, and it has surely

aggraded it recently, but locally the same phenomena are well exemplified where the valley is distinctly terraced, the terraces and flood-plain all sloping toward the stream indicating progressive down-cutting.

If rills running over loose materials may be regarded as overloaded streamlets, and if it be assumed that the surface of a ridge is washed by such streamlets behaving as here described, and capable of carrying away from a given point more material than they bring, we have the conditions for the continued down-cutting of broad slopes without cutting valleys and for the lowering of a ridge without its subdivision into hills; it may be at a rate which is uniform throughout its length. Thus a broad area consisting of hills and ridges of uniform height may be cut down in such a manner as approximately to preserve their uniformity of height and the flatness of the sky line.

St. Louis peneplain.—Before going further it may be stated that this discussion was not begun with an academic interest, but in an attempt to explain what appears to be a case of just such uniform down-cutting as is here assumed. The area in question is the St. Louis quadrangle and adjacent territory. It is a low plateau with a mature drainage system. The ridges and very narrow remnants of upland rise to such a uniform height that no physiographer would hesitate to pronounce them the remnants of a former plain of very faint relief (in this case a peneplain as shown by abundant evidence). Furthermore the supposition would be that the horizon of the former plain was approximately that of the present hilltops.

Above the uniform level of the hilltops are a few exceptional elevations of fifty feet or more. Capping these are deposits of typical Lafayette gravels from ten to twenty feet thick. No theory of the origin of the Lafayette formation which receives any credence, admits the supposition that these gravels might have been deposited on exceptionally high points in preference to a lower surrounding plain. If the elevations on which they now rest existed as such when the gravels were deposited, it would seem necessary to assume that the entire surrounding plain was buried by gravel to a depth equal to the height of these hills plus the thickness of the deposit on the hills. It must then be assumed that subsequent erosion was guided in such a manner as to strip practically the whole of this thick bed of gravel from the surrounding plain while leaving the thin deposit on

the hilltops. To avoid this improbable supposition it might be assumed that the gravels were laid down on a plain whose elevation is represented by that of the present exceptional hills and that a post-Lafayette peneplain was developed 50 or more feet lower.

Hypothesis of rill-wash applied to the St. Louis region.—As a modification of, or substitute for this last hypothesis, the following is suggested: After the deposition of the Lafayette gravels on a nearly flat surface, uplift followed and the area was maturely dissected by a drainage system which was to some extent ready made, having held over from former conditions and which, therefore, to a certain degree, began its work simultaneously on the entire area. The gravel was in the main removed, except from a few patches between the head waters of streams flowing northwest to the Missouri and others flowing southeast to the Mississippi. It remained in these places partly because they were flatter and therefore less subject to erosion, and partly because, lying between headwaters, they were the last to be reached by erosion. With the exception of these spots the topography of the area was then one of comparatively even-topped ridges and valleys, but without flat uplands. Both while this dissection was in progress and subsequently, unconcentrated wash (as described above) lowered these ridges fifty or more feet. This was not effective on the gravel-covered hills, partly because of their relative flatness, but largely because percolation obviated wash.

The difficulty in such a conception lies in the uniformity of the down-cutting of all the ridges and the consequent preservation of the typical form of a dissected peneplain. This arises from our habit of thinking of rills as small rivers, each incising its own little valley and absorbing its neighbors as soon as a slight advantage has been gained. If the above theoretical reasoning pertaining to rill-wash be correct, this difficulty disappears. The struggle for existence (so characteristic of gullies) disappears from the community of rills as soon as each is seen to be overloaded. Stability then takes the place of instability and there is no longer any difficulty in maintaining an undissected slope while degradation proceeds. Under these conditions a large number of subequal ridges constituting a dissected plain will be degraded at a subequal rate.

It should be made clear that the correctness of the theoretical

reasoning above is not dependent on its application to the St. Louis region. This illustration is not brought forward to prove the argument but to show the nature of the problem in which the question occurs.

It should also be noted that the case of uniform down-cutting over a wide area implies a mature drainage system throughout. In the first dissection of a plateau this condition is reached first near the edge, hence the whole plateau cannot be simultaneously lowered. The erosion of an uplifted peneplain may, however, begin with a ready-made drainage system, the whole of which soon becomes incised. The whole area has, therefore, something of an even start in down-cutting.

Bearing of these principles on profile, and cross-section of valleys.—Returning to the principles, let us examine their bearing on the profile and cross-section of the young valley. Whether there is or is not any progressive union of overloaded rills, the power of such wash increases as the slope is descended, though it is not necessary to assume that the rills become less overloaded, for their load is likewise increasing. The reason for the increase of power lies in the increased amount of water. It is to be assumed that the fall of rain is equal throughout the slope, but since some of the descending water fails to percolate, the amount which joins the run-off is cumulative as the slope is descended. The effect of increasing power in this case is *increasing slope.*

Increase of slope as the result of increase of power is contrary to our customary conceptions gained from constant attention to rivers in which the reverse is usually true. A brief statement of the geometrical principle involved may therefore be necessary. Where a current is limited in its down-cutting by a certain level beneath which it cannot cut, additional power results in cutting nearer to that level and flattening the profile. Where the opportunity for down-cutting is not thus limited, the current is free to cut downward in proportion to its power and the effect of progressively increasing power is *a progressively steepening profile.* This is the case where a cutting stream encounters a fall. Both the principle and the form are illustrated in the rapids above all falls. However low the fall may be, it removes the upper stream entirely from the influence of the limiting level

below, and that level has no existence for the current above the fall. Nor is it necessary that the fall be vertical; the principle is the same in the approach to a cataract or cascade or other exceptionally steep slope, though its application is less simple.

Applying this principle to the case of rill-wash, we recall that the end of the overloaded condition and the beginning of gully-cutting is sudden. The effect of this is a steep offset which allows the rills to cut down without reference to any lower limit. The effect of this, in turn, is progressively increased slope as the fall at the gully-head is approached. This gives, above the gully-head, a profile which is convex upward, which gives way in the young valley itself to a profile of decreasing slope, that is, one which is concave upward. It will readily be seen that this description fits the case of the simple gully developed on a simple slope. Indeed the compound curve thus formed is very general despite all complexities due to sod covering and initially complex slopes.

A similar convexity of the upper slope is seen in the cross-section of a young valley. The existence of the valley removes from the wash on at least the upper part of the slope, the influence of the level which limits down-cutting. In all cases, therefore, except where peculiar conditions are assumed, the wash increases in power for a small distance at least, while the slope is concurrently steepened, producing a curve which is convex upward. If the valley be deepening, this convexity approaches more or less close to the axis, and, if the deepening be sufficiently rapid, the convexity reaches the channel making the entire slope from hilltop to stream convex upward. Where this is the case, the down-cutting of the valley axis is sufficient to leave the rill-wash on the entire slope free from the influence of a lower limiting level. Where down-cutting is less rapid, the wash near the stream comes within the influence of a lower limit and shapes its profile according to the laws of streams, that is, it becomes concave upward. The result is the U-shaped valley. The point to be emphasized here is that not only does this form *not* imply a cessation of down-cutting, but that it does not even imply lateral corrasion by the stream. The only requisite is that the stream shall cut down slowly enough so as *not* to remove from the wash on the side slopes the influence of a lower limit. In the area mentioned near St. Louis

it is quite the rule that the sides of the smaller valleys are upwardly convex from top to bottom.

In the course of its development the young valley whose cross-section shows simple curves increasing in steepness as the axis is approached, exchanges these for compound curves as described above. The stage of development at which this exchange is made depends partly on the absolute rate of down-cutting of the axis and partly on the behavior of the wash. A full explanation of the latter would involve discussion of materials composing the surface. Observation indicates that with a given rate of down-cutting a loess cover is specially favorable to valleys, whose sides increase in steepness down to the axis, that is, are simple curves and upwardly convex.

A STUDY OF RIVER MEANDERS ON THE MIDDLE ROUGE[1]

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Given a stream flowing on a flat surface of homogeneous material, will it meander? If so, will the meanders develop at once, or will they be formed only after considerable time has elapsed? The answer to these questions was actually encountered in a millpond which had silted up for many years till its floor was level. Then the dam broke causing the river to flow in a narrow channel through the deposits. It is hoped that the behavior of the stream under these conditions may shed some light on the general question of the origin of meanders.

The conception generally held is, that the stage in the lives of rivers when they meander in broad arcs is reached late, when they flow sluggishly, as swift streams are less easily turned aside than those which flow less impetuously.

This supposes a turning aside from a straight course due to irregularities or obstructions in the path of the stream. The breaking out of ditches into meanders is held to support this view. This view of the origin of meanders is the one stated by Geikie, Russell, Davis, Chamberlin and Salisbury, and other authorities. It is also held in some quarters that meandering is a direct result of loading of the stream and deposition of the sediment.[2]

This paper concerns itself with a discussion of an actual case of meander development and shows that meanders may develop in a swift stream, that they are not always the result of a long process; but may develop immediately, and that inequalities of bed or obstructions in the path of the stream are not necessary for their formation.

The river on which meander development was studied was the Middle Rouge, one of the three upper branches of the River Rouge,

[1] This case of meandering was discovered when on a field trip with Professor M. S. W. Jefferson of the Ypsilanti State Normal.

[2] Griggs, *Bull. Am. Geog. Soc.*, Vol XXXVIII, pp. 168–76.

a stream emptying into the Detroit River, as shown on the accompanying map of the vicinity, designed to show the relation of the locality to the surrounding country.

Some seventy-five years ago a dam was built across the Middle Rouge near Pikes Peak. Since that time the dam has been maintained continuously, except that it broke in 1895. It was, however, immediately repaired so that to all intents and purposes the water has been ponded up continuously for about three quarters of a century.

The floor of the pond is composed of silt of very uniform char-

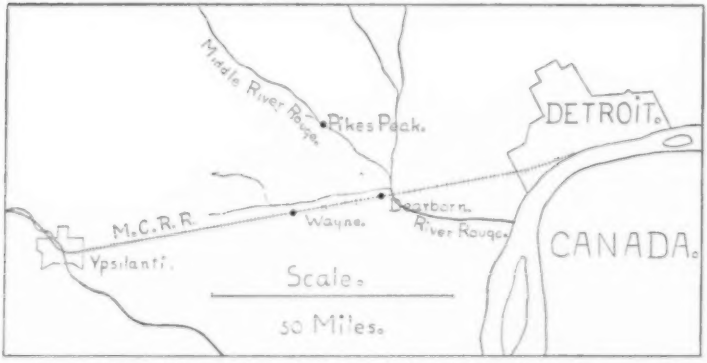

Fig. 1.—Map of the vicinity to show the relation of the locality to the surrounding country.

acter. Deposited under water as it was, and attaining a thickness of several feet, it presented a material of exceptional character for the river to cut into when the water was withdrawn from the surface by the break in the dam. The uniform character of the deposit, so far as any illustration can show it, is shown in Fig. 3, taken about 600 ft. above the dam on the right-hand bank of the stream.

The deposit, which is a fine even clay with absolutely no bowlders or stones, has cracked extensively, and to considerable depths since the withdrawal of the water, and these cracks show plainly in the photograph. The vegetation (*Polygonum*) also shows; but as the picture was taken after snow had fallen, late in November, the luxuriance of its growth is not apparent.

The margins of the pond when first the dam was built, must have been the bluffs on either side of the flood plain and the pond must have extended back half a mile from the dam as is shown by the deposits. The pond when the dam broke, was much smaller, due to deposits of silt, its limits at the head of the valley being marked by the peculiar hummock or mound configuration built up by the sedge

Fig. 2.—Break in Dam (looking S. E.). During high water on May 30, 1905, the dam gave way leaving a break at the end of the waste weir and bridge as shown in Fig. 2. When the water was drawn off, the floor of the pond was almost entirely covered with Knotweed (*Polygonum Muhlenbergii*) standing from three to five feet high.

(*Carex stricta*) and added to later by turf-forming grasses.[1] These tuft formations mark off sharply the limits of the pond on the margins away from the dam and shown in Fig. 4. Here the stream has cut a narrow channel in the bed of the old, wider course, but preserved the old bed, the banks of the old course being marked off sharply, the

[1] Brown, *Bot. Gaz.*, October, 1905, p. 270.

hummock configuration showing on either shore, but better on the right.

The same is shown in the view of the entire valley (Fig. 5) in the foreground, where the present stream has inherited an old meander. This view down the river shows the bridge in the background and the bluffs on the left hand side of the valley. The wagon road

FIG. 3.—Section of silt where stream has cut seven feet into old pond floor.

also shows, and over to the left the houses at Pikes Peak may be seen. The character of the surface, with its tuft formations, the land reclaimed from the original pond by silting and subsequent additions by the growth of vegetation, also shows very well.

The meander which shows is an inherited one, cut by the river in silt laid down in the original pond while the water was still ponded up, and deepened in a narrower channel since. The old banks show plainly on either side.

The bars on the inner side of the curves are of small extent and

relatively steep slope, as the lateral cutting of the stream has as yet been very little. One of these bars shows in the foreground. They are in general composed of coarse material (sand and gravel), differing in composition from the banks of the stream.

The Rouge is so called from its color, which is owing to the sediment carried. The Middle Rouge, even though a small stream here, carries a great amount of sediment. A large portion of this was

FIG. 4.—Present stream in an inherited wider bed.

dropped in the pond while the dam was intact, the deposits reaching a depth of eight feet at the dam and extending back a distance of nearly half a mile.

The map accompanying the paper (Fig. 6) shows the meandering course of the stream in the old floor of the pond and extends back far enough to show all the meanders which have developed since the withdrawal of the water as well as one (the first of the series), which was developed earlier and has since simply been deepened.

The map has been constructed with considerable care, the principal

points being located accurately, and the width of the stream measured carefully in many places.

At the present time, the river has cut through the old deposits and has regraded its floor so that the deposits stand out eight feet thick at the dam and thin out to nothing half a mile up stream.

Assuming that the floor of the pond is level, and it must be very nearly level when we consider that the top of the waste weir is

FIG. 5.—View down the river taken from bluffs at the head of the old mill pond.

only eleven feet above the bed of the stream and the silt reaches to within three feet of its top, we can see that when the dam gave way the river was flowing on a nearly level surface, certainly more nearly level than any other portion of the flood plain in the vicinity. It immediately began to cut into this deposit, however, and soon had a fall in half a mile of a trifle more than the thickness of the deposits, or something over ten feet.

To have been there and seen the events as they actually occurred would have been exceedingly interesting. Nothing could be learned

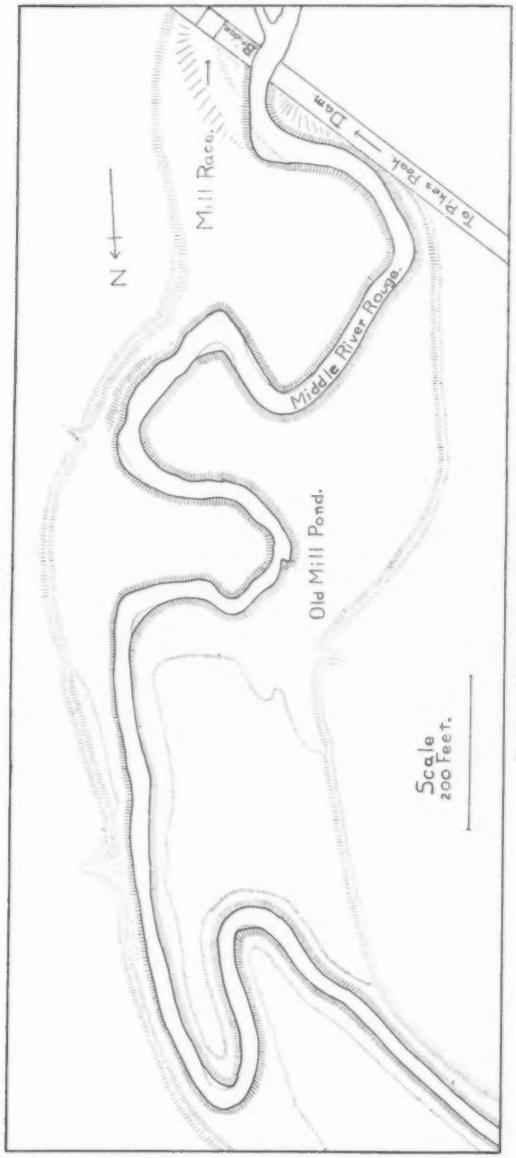

FIG. 6.—Map of the mill-pond at Pikes Peak.

in the vicinity, however, which seemed reliable enough to be taken as authority as regards the course of events, so it will be necessary to imagine what actually did occur from the final results.

The river, when first the dam broke, must have been free to flow on a practically flat surface, at least not uneven enough to cause it to swing from one side of the plain to the other. Neither can the character of the deposits have been the cause of the meandering which actually occurred. These meanders may or may not have been assumed practically as soon as the dam broke and deepened and made permanent since.

The meanders developed on the withdrawal of the water from the pond are not the old ones which the stream simply resumed with slight deviation. The old meanders were completely obliterated by silting. If this were not so, we should expect to find traces of old meanders which the present stream does not occupy, but which would be plainly visible as slight depressions in the valley floor. These we do not find in the floor of the old pond, though they occur both above and below in the valley floor. In fact, several "cut offs" have had time to form in the old deposits above water at the time the dam broke, farther up stream than shown on Fig. 6, but still in silt laid down in the original pond.

The old topography of the valley floor was not reproduced on the withdrawal of the water due to pressing out of the water entrapped in the subaqueous deposit by the increased gravity of the mass. It this were so, it would be peculiar that only one set of meanders should be produced and the stream should follow them. Others would show as well. The material deposited was a very fine, even clay and the amount of settling which it would undergo on the withdrawal of the water, from a shallow pond perhaps three or four feet deep would be problematical, and perhaps of more theoretical than practical importance in the determination of the course of a stream whose course was determined within a few hours after the break in the dam.

The silting up of the pond was certainly complete enough to obliterate entirely the old stream courses and the settling of the mass which would occur in 24 hours did not reproduce them. The new meanders are independent of the old.

The probability is, that while the water of the pond was draining

off, the flat character of the bottom caused the water to flow in a thin broad stream, and that the meanders were caused or formed as the narrower stream cut back from the dam. This is rendered probable by the fact that near the dam, in so far as there are any inequalities of surface, the water does not occupy the lowest land. This would tend to show that inequality of surface was not the determining factor in causing the meandering. The question naturally arises: What did cause the stream to meander?

According to the U. S. contour map of the locality, the average fall of the stream per mile is about ten feet above the old pond and about six feet below. If the stream had assumed a straight path, it would have had a fall of over thirty feet to the mile in the floor of the old pond. As a matter of fact, it, by its meandering course, reduces the fall to about fifteen feet to the mile. These numbers are only approximations; but can be verified by consulting the accompanying map. Even this is more than the average fall per mile in the course of the stream. This is what we should expect, as while in the old pond the stream has graded its course, it is still cutting down to conform to the grade of the stream as a whole, which it will reach in time.

Considering the width of the flood plain, however, it will be seen that it would be impossible for the stream to decrease its rate of fall farther by meandering, as it already swings from side to side, cutting into both boundary bluffs. In so far as the conditions permit, the stream has apparently endeavored to conform to the general grade of its course in its path across the floor of the old pond. This gives rise to some very interesting questions.

What does meandering mean? Does it mean a response to surface configuration? Is it dependent upon the nature of the material in which the river is cutting its course? Does it bear any relation to stream velocity? Is it necessarily associated with the lower courses of streams because of a decrease in velocity, or is it because of a decrease in freedom to meander due to the width of the flood plain caused by lateral cutting?

These meanders are not inherited, neither are they the result of lateral cutting. Most of the work done by the river since the dam gave way has been vertical cutting. The banks are vertical and remain so on account of the fine, homogeneous clay of which they are

composed. Only in an occasional place, and then only in small amount, has any lateral cutting whatever occurred.

What then does meandering mean? It would seem from this one case, that meandering is rather an expression of the river's attempt to establish a certain grade and fix a certain relation between its slope and the amount of sediment carried, that meandering is not dependent upon the character of the material and may proceed in deposits in which there are no obstructions to start meandering, that meanders are not always the result of a long process, but that a meandering course may be the one first chosen, and that a swift stream, when free to assume the path it chooses, will meander.

This is, of course, more in the nature of a suggestion than a definite statement as to the cause of meandering, as one case is not sufficient to establish the point, but it should be possible to find many other examples of character similar to this, and a careful study of such cases would certainly help us to a better understanding of the behavior of meandering streams.

REVIEW OF NOMENCLATURE OF KEWEENAWAN IGNEOUS ROCKS[1]

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The Keweenawan igneous rocks of the Lake Superior region have been studied and discussed by many geologists during the past thirty years. At the beginning of that period microscopical petrography was in its infancy, and minor errors due to faulty methods inevitably resulted. In the course of the years these have been gradually corrected, involving changes of nomenclature. Some variations in nomenclature have resulted from the varying points of views of the authors. But the general progress of petrography has brought more numerous and important modifications.

In order to make the names used by the prominent writers on the subject more readily intelligible, a correlation of these is presented herewith. It must be remembered that, since the basis of petrographic classification used by the authors has varied somewhat, such a correlation can be only an approximation, but it will nevertheless serve the purpose of showing the various changes that have occurred, and of presenting, at least in its outlines, the main facts of nomenclature of each writer.

In order to give precision to such a correlation, it is desirable that the nomenclature of each writer be compared, not simply with that used by other authors, but also with an expressed and definite classification. Therefore the following classification has been prepared, on the basis of textures and mineral composition. It is not a general classification of igneous rocks, but is intended to include merely the types represented in the Keweenawan of the Lake Superior region.

Macfarlane,[2] in 1866, described the Keweenawan rocks of Michipicoten Island. He found melaphyre, trap, amygdaloid, quartz porphyry, porphyrite, and trachytic phonolite. His "quartz porphyry,"

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Thos. Macfarlane, *Geol. Surv. of Canada, 1863–66*, 1866.

which occurred at the contact of the sandstone and trap, was doubtless a modified quartzite. His "trachytic phonolite" is not fully described, and correlation is uncertain.

J. H. Kloos,[1] in 1871, described gabbro or hypersthenite, black porphyry or melaphyre, porphyry and amygdaloid. The first named was probably a gabbro and the second a diabase.

Pumpelly,[2] in 1873, described melaphyre, trap, and amygdaloid without microscopic study; he distinguished three kinds of melaphyre, coarse-grained, fine-grained, and melaphyre porphyry. Correlations of these names are impracticable, and would be misleading rather than helpful.

Marvine,[3] in the same year, described melaphyre, trap, diorite, and amygdaloid. Pumpelly later claimed, probably correctly, that Marvine's diorite included samples of diabase, melaphyre, and gabbro but no true diorite.

Streng,[4] in 1877, described melaphyre, melaphyre porphyry, and hornblende gabbro from the Keweenawan of Minnesota. He published chemical analyses of two of these which permit their correlation on the quantitative basis (see Table III).

Pumpelly,[5] in 1878, described the alterations which some of the Keweenawan rocks had suffered in great detail, but brought to light no additional varieties of the unaltered rocks.

The same author,[6] in 1880, identified eight or ten kinds of igneous rocks in the Keweenawan (see the correlation table). He distinguished diallage from augite by means of the parting in the former, and, in accordance with the usage at that time, called a massive igneous rock containing plagioclase and diallage a gabbro, while one containing plagioclase and augite he called a diabase. But in his descriptions and illustrations, his diabase seems to have an ophitic texture in all cases. His identifications of the various plagioclase feldspars were all based on incorrect methods, so that his so-called

[1] J. H. Kloos, *Zeitschrift der deutschen geologischen Gesellschaft*, p. 417, 1871.

[2] R. Pumpelly, *Geol. of Mich.*, Vol. I, Pt. 2, 1873.

[3] A. R. Marvine, *ibid.*

[4] A. Streng, *N. J. Min. Geol.*, 1877.

[5] R. Pumpelly, *Proc. Amer. Acad.*, Vol. XIII, p. 285, 1878.

[6] R. Pumpelly, *Geol. Wis.*, Vol. III, pp. 27–49, 1880.

Textures	Chief feldspar orthoclase		
	+ Quartz		
	± Mica ± Amphibole ± Pyroxe		
	± Microcline	+ Anorthoclase	
Granitic	Granite	Soda granite	Syen
Ophitic			
Porphyritic (Phenocrysts prominent)	Rhyolite Porphyry (Quartz porphyry)	Quartz Keratophyre	Trach Porph
Felsitic or Porphyritic (Phenocrysts few)	Rhyolite	Quartz Keratophyre	Trach
Fragmental	Acid tuffs		
Glassy	Obsidian		

TABLE I.—M

	Orthoclase with equal plagioclase			
− Quartz		With quartz		
roxene		+ Monoclinic pyroxene		+ O P
± Microcline		+ Orthoclase	− Orthoclase	
Syenite	Monzonite	Orthoclase Gabbro	Quartz Gabbro	
		Orthoclase Diabase	Quartz Diabase	Ensta
Trachyte Porphyry				
Trachyte				

TABLE I.—Mineralogical Classification of Keweenawan Igneous Roc

	Orthoclase with equal plagioclase					
– Quartz		With quartz				
		+ Monoclinic pyroxene		+ Orthorhombic Pyroxene	+ Amphibole ± Biotite	No ferro-magnesi mineral
- Microcline		+ Orthoclase	– Orthoclase			
	Monzonite	Orthoclase Gabbro	Quartz Gabbro	Quartz Norite	Quartz Diorite	Plagioclasite
		Orthoclase Diabase	Quartz Diabase	Quartz Enstatite diabase		
					Dacite	

Chief feldspar plagioclase						
Without quartz						
agnesian eral	+ Amphibole ± Biotite	+ Monoclinic Pyroxene		+ Orthorhombic Pyroxene		
		− Olivine	+ Olivine	+ Monoclinic Pyroxene	− Olivine	+ Oliv
clasite	Diorite	Gabbro	Olivine Gabbro	Augite Norite	Norite	Olivi Norit
		Diabase	Olivine Diabase	Hypersthene Diabase		
	Andesite Porphyry	Augite Andesite Porphyry	Basalt Porphyry			
	Andesite	Augite Andesite	Basalt			
						Basalt Tuffs
						Tachylyte

hout quartz			
ne	+ Orthorhombic Pyroxene		
- Olivine	+ Monoclinic Pyroxene	− Olivine	+ Olivine
Olivine Gabbro	Augite Norite	Norite	Olivine Norite
Olivine Diabase	Hypersthene Diabase		
Basalt Porphyry			
Basalt			
			Basalt Tuffs
			Tachylyte

		No feldspar	
	+ Olivine	± Pyroxene ± Amphibole ± Biotite	
livine		− Olivine	+ Olivine
ivine rite	Troctolite	Pyroxenite	Peridotite

albite and oligoclase are actually andesine-oligoclase, his labradorite is andesine, and his anorthite is chiefly labradorite with some bytownite.

Irving[1] followed the practice of Pumpelly, but described about twice as many petrographic varieties. He protested against the practice of basing rock names on any such distinction as that between diallage and augite, but followed the custom, nevertheless, in the main, although he tried to discriminate between diabase and gabbro on the basis of coarseness of crystallization, assigning the name gabbro to the coarser grained varieties. Irving's orthoclase gabbro has been called hornblende gabbro by Wadsworth, and porphyritic gabbro by N. H. Winchell; it is nearly the same as Lane's gabbro aplite; recently it has been called oligoclase gabbro by F. E. Wright.[2]

N. H. Winchell,[3] in 1881, described thin sections of dolerite, labradorite rock, hyperite, and gabbro. He made the name "dolerite" so general in meaning as to include gabbro, diabase, olivine gabbro, olivine diabase, augite andesite, and basalt. His "labradorite rock" was called "anorthite rock" by Irving, and is now called plagioclasite (or anorthosite), while his hyperite is now known as norite.

Wadsworth,[4] in 1887, proposed a new classification of the Keweenawan igneous rocks on the basis of the alterations which a given type has undergone. Thus, a gabbro whose augite had altered to hornblende he would call a gabbro, diorite. A peridotite may by alteration become a serpentine or a talc schist; in either case Wadsworth would call it still a peridotite, adding a name to indicate its present condition. Consequently, a rock called, for example, a gabbro by Wadsworth, may belong to any one of a dozen types as commonly recognized. Nevertheless, Wadsworth's names as actually applied in this case may be correlated approximately with the names of other writers, as shown in the table.

Wadsworth indorsed Irving's protest against using the distinction

[1] R. D. Irving, *Geol. Wis.*, Vol. III, pp. 167–206, 1880; *Mon. V. U. S. G. S.*, 1883, and *Geol. Wis.*, Vol. I, p. 340, 1883.

[2] F. E. Wright, *Science*, Vol. XXVII, p. 892, June, 1908.

[3] N. H. Winchell, *Proc. A. A. A. S.*, Vol. XXX, p. 160, 1881.

[4] M. E. Wadsworth, *G. N. H. S. Minn.*, Bull. 2, 1887.

between augite and diallage as a basis of rock classification, and yet, like Irving, he used it. He did not discriminate sharply between the ophitic and the poikilitic textures, both of which may be found, sometimes together, in Minnesota diabases.

Bayley,[1] in 1889–97, described the gabbro bathylith of Minnesota in considerable detail, and also studied the peripheral phases of the gabbro. To emphasize the close connection in origin between the peridotite and the gabbro of the district, he called the former nonfeldspathic gabbro. Although some of the peripheral phases described by Bayley may be of later date than the gabbro, if we assume that they all belong in the Keweenawan, we find that Bayley recognizes not only augite syenite of Irving, but also a porphyritic equivalent which he calls quartz keratophyre on account of the presence of anorthoclase. He speaks of olivine pyroxene aggregates which should apparently be correlated with wehrlite, dunite, and pyroxenite.

In the peripheral phases he finds a texture which he considers somewhat characteristic; it consists of the presence of many rounded grains of the more important constituents inclosed by other minerals. Bayley calls it the granulitic texture. It has been called the contact structure by Salomon, and the globular by Fouqué. It is well described by the term globular or globulitic.

Grant,[2] in 1893 and 1894, described gabbro, diabase, granite, and fine-grained rocks previously called muscovadites in the Minnesota reports. Grant's granite is the equivalent of Irving's augite syenite, later called soda augite granite by Bayley (see the correlation table). The fine-grained rocks, called muscovadites, include border facies of the gabbro mass of various types, but especially norite, fine grained gabbro often with hypersthene, olivine norite, cordierite norite, etc.

Hubbard,[3] in 1898, described various types of the Keweenawan of Keweenaw Point. His melaphyre is chiefly andesite or basalt;

[1] W. S. Bayley, *Am. J. Sc.*, Vol. XXXVII, p. 54, 1889; Vol. XXXIX, p. 273, 1890; *U. S. G. S.*, Bull. 109, 1893; *J. G.*, Vol. I, p. 433, 1893; Vol. II, p. 814, 1894; Vol. III, p. 1, 1895; *U. S. G. S.*, Mon. 28, p. 519, 1897.

[2] U. S. Grant, *G. N. H. S. Minn.*, 21st Ann. Rep., p. 5, 1893; 22d Ann Rep., p. 76, 1894.

[3] L. L. Hubbard, *Geol. Surv. Mich.*, Vol. VI, Pt. 2, 1898.

TABLE II

CORRELATION OF NOMENCLATURES OF

R. Pumpelly 1880	R. D. Irving 1880–1883	M. E. Wadsworth 1887–1893	W. S. Bayley 1889–1897	L. L. Hubbard 1898
	Granite			
Quartz porphyry	Quartz porphyry			Porphyry
				Felsite
	1 Augite syenite 2 Granitell		1 Granite 2 Soda augite granite	
	Granitic porphyry		Quartz keratophyre	
	Quartzless porphyry			
Felsite porphyry	1 Felsite? 2 Felsitic porphyry			Felsite
		Quartz biotite diorite		
1 Augite diorite 2 Melaphyre	1 Hornblende gabbro 2 Orthoclase gabbro	Altered gabbro	Hornblendic gabbro	
	Orthoclase diabase			
			Quartz diabase	
		1 Gabbro? 2 Quartz diorite	Quartz diorite	
	Anorthite rock			
	Diorite?			
	Quartzless porphyry			Doleritic melaphy
	Diabase porphyrite	1 Augite Andesite 2 Hornblende porphyrite		1 Felsite porphyr 2 Melaphyre
1 Diabase 2 Gabbro	1 Diabase 2 Gabbro			Doleritic melaphy
1 Diabase 2 Gabbro	1 Diabase 2 Gabbro	Diabase	Diabase	Diabasic melaphy
Porphyritic diabase	Diabase porphyrite			
	1 "Ashbed" diabase 2 Diabase porphyrite		Porphyrite	Porphyrite
	1 Olivine diabase 2 Olivine gabbro		Olivine gabbro	
1 Chrysolitic diabase 2 Melaphyre	1 Olivine diabase 2 Olivine gabbro 3 Melaphyre	1 Diabase 2 Granophyrite	1 Olivine diabase 2 Olivine gabbro	Ophitic melaphyr
	Diabase porphyrite			Doleritic melaphy
"Ashbed" Diabase	1 Diabase porphyrite 2 Melaphyre	1 Basalt 2 Melaphyre		Melaphyre
			Hypersthene gabbro	
	Norite			
		1 Forellenstein 2 Troctolite		
			Granulitic pyroxene rock	
			Nonfeldspathic gabbro	

LE II

S OF KEWEENAWAN IGNEOUS ROCKS

ubbard 98	A. C. Lane 1898–1906	A. N. Winchell 1900	N. H. Winchell and U. S. Grant 1900	Mineralogical Classification
			Granite	Granite
	Quartz porphyry		Quartz porphyry	Rhyolite porphyry
	1 Felsite 2 Felsophyre 3 Orthophyre		Rhyolite	Rhyolite
			Tuff	Acid tuffs
			Obsidian and apobsidian	Obsidian
	1 Augite-porphyrite? 2 Granophyre 3 Augite syenite 4 Gabbro aplite		1 Granite 2 Soda granite	Soda granite
			Quartz keratophyre	Quartz keratophyre
			Syenite?	Syenite
	Quartzless porphyry			Trachyte porphyry
	1 Felsite 2 Orthophyre		Trachyte	Trachyte
			Syenite or Granophyre	Monzonite
	Gabbro aplite?	Orthoclase gabbro	Porphyritic gabbro	Orthoclase gabbro
				Orthoclase diabase
		Quartz gabbro	Quartz gabbro	Quartz gabbro
	1 Quartz diabase 2 Diabase granophyrite		Diabase	Quartz diabase
			Quartz norite	Quartz norite
	Enstatite diabase		Diabase with hypersthene	Quartz enstatite diabase
			Quartz diorite	Quartz diorite
	Quartz porphyrite			Dacite
		Plagioclasite	Anorthosite	Plagioclasite
			1 Diorite 2 Gabbro	Diorite
elaphyre			Porphyrite	Andesite Porphyry
orphyrite re	1 Felsite porphyrite 2 Felsophyrite		Andesite	Andesite
elaphyre		Gabbro	1 Gabbro 2 Diabase	Gabbro
elaphyre	Diabase (in dikes)	Diabase	Diabase	Diabase
	1 Porphyrite 2 Labradorite porphyrite		1 Diorite porphyrite 2 Diabase porphyrite	Augite andesite porphyry
	Augite andesite		Basalt	Augite andesite
		Olivine gabbro	Olivine gabbro	Olivine gabbro
laphyre	1 Melaphyre ophite 2 Melaphyre porphyrite 3 Olivine diabase (in dikes)	Olivine diabase	Diabase with olivine	Olivine diabase
elaphyre	Melaphyre dolerite		Porphyritic basalt or zirkelite	Basalt porphyry
	1 Felsite 2 Melaphyre porphyrite 3 Labradorite porphyrite	Basalt	Basalt	Basalt
			Tuff or zirkelite	Basalt tuffs
			Zirkelite	Tachylyte
			Hypersthene gabbro	Augite norite
			Norite (muscovadite)	Norite
	Enstatite diabase		Hypersthene diabase	Hypersthene diabase
			Norite with olivine	Olivine norite
	Troctolite	Troctolite	Forellenstein or troctolite	Troctolite
			Pyroxenite	Pyroxenite
		Peridotite	Peridotite	Peridotite

his doleritic melaphyre is a coarser basalt, or a gabbro; his ophitic melaphyre is a poikilitic and luster-mottled diabase; and his porphyrite is chiefly andesite and trachyte.

Lane,[1] in 1898–1906, described the Keweenawan rocks of Isle Royale and northern Michigan. His melaphyre porphyrite is the equivalent of Pumpelly's "Ashbed" diabase and Irving's diabase porphyrite, Lane's melaphyre ophite is an olivine diabase, luster-mottled by means of poikilitic textures; his doleritic melaphyre is a basalt porphyry. Lane would confine the name diabase to dike rocks. His augite syenite is said to be at least in part an equivalent of Bayley's quartz diabase. He uses the term "ophitic" in a narrow sense, not justified by the original definition of Michel Lévy,[2] nor by his usage.[3] He applies it to those luster-mottled rocks in which single pyroxene individuals inclose several plagioclase crystals, usually lath-shaped and irregularly placed. It is, thus, for Lane, a variety of the poikilitic texture. In its original meaning, still commonly used by many, and adopted here, it refers to that texture of a basic igneous rock produced when the plagioclase crystallizes in lath-shaped forms before the pyroxene solidifies.

A. N. Winchell,[4] in 1900, described in detail a few samples of the Keweenawan rocks of Minnesota. He used the new term plagioclasite for the rocks previously known usually as anorthosites.

N. H. Winchell and U. S. Grant[5] published in 1900 by far the most complete accounts of the petrography of the Keweenawan igneous rocks. Their nomenclature varies very little from that commonly in use at present. They described practically all the petrographic types of the Keweenawan previously known and added some half dozen new varieties. They used diorite porphyrite or diabase porphyrite to designate more or less ophitic types of andesite porphyry or augite andesite porphyry. They used Wadsworth's

[1] A. C. Lane, *Geol. Surv. Mich.*, Vol. VI, Pt. 1, 1898; *Geol. Soc. Amer.*, Bull., Vol. XIV, pp. 369, 385, 1903; *J. G.*, Vol. XII, p. 83, 1904; *Geol. Surv. Mich.*, Ann. Rep., 1903, pp. 205, 239, 1905; *Geol. Surv. Mich.*, Ann. Rep., 1904, p. 113, 1905; *Proc. L. Sup. Mg. Inst.*, Vol. XII, p. 85, 1906.

[2] *Bull. Soc. Geol. Fr.*, Vol. VI, 1878, p. 158.

[3] *Minéralogie micrographique*, 1879, Pl. XXXVI. See also p. 153.

[4] A. N. Winchell, *Amer. Geol.*, Vol. XXVI, pp. 151 (197), 261, 348 (1900).

[5] N. H. Winchell and U. S. Grant, *G. N. H. S. Minn.*, Fin. Rep., Vol. V, 1900.

name zirkelite for a devitrified basalt, basaltic tuff, or tachylyte; devitrified obsidian they called an apobsidian, and a devitrified rhyolite an aporhyolite, as suggested by Bascom. Wadsworth's quartz biotite diorite is called syenite by Grant. It is an intermediate type corresponding to a monzonite.

The quantitative classification of igneous rocks as proposed by Cross, Iddings, Pirsson, and Washington may be used as the basis of a correlation of the Keweenawan igneous rocks. From a chemical point of view such a correlation (see Table III) is more exact than one based upon the mineral composition and texture, but it can include only those rock types of which satisfactory quantitative analyses are available.

An examination of the table of correlation on this basis will reveal the fact that the number of satisfactory analyses available is not great, especially when compared with the descriptions previously mentioned. Several of the early analyses are not included in the tabulation because of manifest inaccuracy or incompleteness.

The analyses of Streng and Pumpelly are good for the time at which they were made. The norm of Pumpelly's andose is: or 7.78, ab 42.44, an 17.24, hy 1.30, ol 17.97, mt 4.41, il 4.41. The norm of his camptonose is: or 7.23, ab 22.01, an 23.91, ne 4.26, di 22.55, ol 7.47, mt 4.18, il 5.32. The norm of his auvergnose is: or 0.56, ab 16.24, an 36.97, di 15.88, hy 20.34, ol 1.11, mt 3.71, il 1.98. Sweet published two analyses of Keweenawan rocks; the one of diabase from the Ashland mine, Ashland Co., Wis., is wholly unsatisfactory; the other is approximately correct, and classifies as hessose. The analyses of gabbros published by Wadsworth are recalculated in Washington's tables[1] of chemical analyses of igneous rocks; the norm of his diabase granophyrite from the Cleveland mine is: Q 5.10, or 8.34, ab 16.77, an 32.25, di 11.02, hy 9.90, mt 8.45, il 5.17; the norm of his sample from Houghton Co. is: Q 8.46, or 8.90, ab 23.06, an 16.40, di 13.75, hy 20.82, mt 5.80, ap 0.34. Washington's tables give full details regarding the recalculation of the analyses of Keweenawan rocks published by Van Hise, N. H. Winchell, and Bayley. The norms of the analyses reported by Hubbard may be summarized as follows:

[1] H. S. Washington, *U. S. G. S.*, P. P. 14, 1903.

[1] A. Streng 1877	[2] R. Pumpelly 1878	[3] E. T. Sweet 1880	[4–5] M. E. Wadsworth 1887–1893	[6] C. R. Van Hise 1892	[7] N. H. Winchell 1893	[8–11] W. S. Bay 1889–189
						Granite (8) Pigeon Pt., M Soda granite (9 Pigeon Pt., M Quartz keratop Pigeon Pt., M
						Quartz keratop Pigeon Pt., M
			Gabbro (4)? Pigeon Pt., Minn.			Quartz diorite (Pigeon Pt., M
Hornblende gabbro Duluth, Minn.	Melaphyre Middle of bed 87 Eagle River section, Mich.					
Melaphyre porphyry Duluth, Minn.			Gabbro (4) Baptism River, Minn.			
		Diabase Fond du Lac Mine, Douglas Co., Wis.	Diabase granophyrite (5) Cleveland Mine, Keweenaw Pt., Mich.			Olivine gabbro Pigeon Pt., Olivine gabbro T. 61 N. R. 1
			Diabase granophyrite (5) Sec. 2, T. 49 N. R. 27 W. Houghton Co., Mich.			
	Melaphyre Bottom of bed 87, Eagle River section, Keweenaw Pt., Mich.					
	Melaphyre Lower part Bed 64, Eagle River section, Keweenaw Pt., Mich.			Diabase Sec. 13, T. 47 N. R. 46 W. Gogebic Co., Mich.	Gabbro (granular) Bashitanaquab Lake, Minn.	Olivine gabbro Birch Lake, Gabbro (11) T. 64 N. R. Minn.
						Hypersthene g Gunflint La

1–21 See references on page 774.

TABLE III

ENCLATURES OF KEWEENAWAN IGNEOUS ROCKS OF THE LAKE SUPERIOR REGION

7 N. H. Winchell 1893	8–11 W. S. Bayley 1889–1895	12 A. C. Lane 1898	13–16 L. L. Hubbard 1898	17–18 A. N. Winchell 1900–1908	19–21 A. C. Lane 1905–1906	Quantitative Classification
			Felsite (13) Keweenaw Pt., Mich.			I. 3. 1. 2. Magdeburgose
			Felsite (14) (No. 17193A) Keweenaw Pt., Mich.			I. 3. 2. 3. Tehamose
			Felsite (14) (No. 16051) Keweenaw Pt., Mich.			I. 4. 1. 1. Lebachose
	Granite (8) Pigeon Pt., Minn. Soda granite (9) Pigeon Pt., Minn. Quartz keratophyre (8) Pigeon Pt., Minn.					I. 4. 1. 3. Liparose
	Quartz keratophyre (9) Pigeon Pt., Minn.					I. 4. 2. 3. Toscanose
				Plagioclasite (17) Carlton Peak, Minn.		I. 5. 4. 4.5. Labradorose
	Quartz diorite (9) Pigeon Pt., Minn.					II. 4. 2. 3. Adamellose
					Gabbro-aplite (19) Mt. Bohemia, Mich.	II. 4. 3–2. 4. Tonalose-dacose
			Felsite porphyrite (15) Keweenaw Pt., Mich.			II. 5. 1. 4. Umptekose
			Porphyrite (16) Keweenaw Pt., Mich.			II. 5. 2. 4. Akerose
		Porphyrite (V and VI) Isle Royale, Mich.		Orthoclase gabbro (17) Duluth, Minn.		II. 5. 3. 4. Andose
						II. 5. 3. 5–4. Beerbachose-andose
				Quartz gabbro (17) Little Saganaga Lake, Minn.		II. 4–5. 3. 5. Placerose-beerbachose
		Porphyrite (I) Isle Royale, Mich.				II. 5. 3. 5. Beerbachose
	Olivine gabbro (9) Pigeon Pt., Minn. Olivine gabbro (10) T. 61 N. R. 12 W., Minn.	Porphyrite (IV) Ophite (VII) Isle Royale, Mich.		Olivine gabbro (17) Birch Lake, Minn. Diabase (17) Birch Lake, Minn.		II. 5. 4. 4.5. Hessose
						III. 4. 3. 4. Vaalose
				"Ashbed diabase" (18) Bed 65, Eagle River section, Keweenaw Pt., Mich.		III. 5. 2–3. 4. Kilauose-camptonose
				Orthoclase gabbro (17) (Basic part) Duluth, Minn.		III. 5. 3. 4. Camptonose
Gabbro (granular) Bashitanaquab Lake, Minn.	Olivine gabbro (10) Birch Lake, Minn. Gabbro (11) T. 64 N. R. 8 W., Minn			Troctolite (17) Duluth, Minn. Olivine diabase (18) Bed 108, Eagle River section, Greenstone Cliff, Keweenaw Pt., Mich.	Ophite (19) Mt. Bohemia, Mich. Diabase (20) Lighthouse Pt., Mich. Ophite (21) St. Mary Land Co., Keweenaw Pt., Mich.	III. 5. 4. 1, 5. Auvergnose
	Hypersthene gabbro (11) Gunflint Lake, Minn.					IV. 1^1. 1^1. 2. Cookose

	Magdeburgose	Tehamose	Lebachose	Umptekose		Akerose
				No. 17,039	No. 17,007	
Q	38.58	48.90	18.60	1.14	.....	.....
C	1.94	.....	.....	.....	.....	.....
or	39.48	26.13	70.61	20.57	20.57	15.01
ab	16.77	18.34	0.52	57.64	57.64	48.21
an	.....	3.61	.....	1.67	.....	7.78
ne	.....	.....	.....	.....	2.27	3.69
ac	.....	.....	4.16	.....	3.70	.....
ns	.....	.....	3.66	.....	.....	.....
di	.....	0.12	1.43	5.62	0.43	5.18
hy	.....	.....	0.86	2.70	.....	.....
ol	.....	.....	.....	.....	3.22	5.32
mt	0.46	0.70	.....	6.03	5.57	8.12
hm	1.92	1.28	.....	3.04	5.92	4.00
H_2O	0.41	1.03	0.42	2.23	1.23	2.76
Total	99.56	100.11	100.27	100.64	100.55	100.07

It is to be remarked that not one of these rock types described by Hubbard corresponds chemically with any variety described by any other author. The fact suggests possible inaccuracies in Hubbard's analyses.

Lane's analyses, as well as Hubbard's were overlooked and omitted from Washington's tables. Recalculations of the analyses given by Lane yield the following norms:

	Tonalosedacose	Andose		Beerbachose	Hessose		Auvergnose		
		No. V	No. VI		No. IV	No. VII	No. 8 Lighth. Pt.	St. M. Land Co.	Mt. Bohemia
Q	13.08	.....	.....	.....	.....	.....	.....	1.80	.....
C	1.02	.....	.....	.....	.....	.....	.....	.....	.....
or	17.79	6.12	6.12	2.78	1.67	2.78	3.89	1.67	10.01
ab	36.15	28.82	23.58	45.59	28.82	21.48	18.35	20.96	18.34
an	16.96	24.19	30.30	20.02	34.19	41.14	36.14	31.41	31.69
ne	.....	2.84	4.26	.....	.....	.....	.....	.....	.....
di	.....	3.80	18.41	1.30	10.66	10.64	13.52	12.74	1.36
hy	11.06	.....	.....	2.76	1.56	5.76	10.77	12.20	21.62
ol	.....	23.25	2.10	12.58	12.97	6.01	13.06	.....	2.08
mt	2.32	3.94	11.14	11.37	6.50	10.44	3.71	10.67	7.42
hm	.....	.....	.....	.....	.....	.....	.....	2.24	.....
il	1.98	.....	.....	.....	.....	.....	.....	4.10	4.71
ap	.....	.....	.....	.....	.....	.....	0.34	0.34	.....
cc	.....	0.90	2.30	2.00	.....	0.70	.....	1.10	.....
pr	.....	.....	.....	.....	.....	.....	0.36	0.10	.....
H_2O	.....	5.01	3.49	2.82	3.90	1.83	.....	0.67	.....
Total	100.36	98.87	101.62	101.22	100.27	100.78	100.14	100.00	97.23

Lane's gabbro aplite differs in its norm from the orthoclase gabbro of Duluth by a greater abundance of quartz, and also by a greater proportion of alkalies as compared with salic lime. His porphyrite (VI), on the contrary, belongs to the same type (andose) as the orthoclase gabbro. His porphyrite (No. 1) is a beerbachose; the others belong to the classes, hessose and auvergnose, so well represented in the Keweenawan.

The analyses published by A. N. Winchell in 1900 were recalculated by Washington with the exception of that of the troctolite, the norm of which is: or 2.22, ab 7.86, an 28.63, ne 5.11, di 5.91, ol 30.21, mt 10.67, il 4.41, MnO 0.08, H_2O 5.23.

In view of the scarcity of analyses of the typical volcanic rocks of the Keweenawan the following new analyses are of much interest. They were made by George Steiger in the laboratory of the Survey.

ANALYSES OF KEWEENAWAN DIABASE

	No. 1*	No. 2†
SO_2	47.69	50.07
Al_2O_3	16.02	12.63
Fe_2O_3	2.41	3.84
FeO	8.70	10.30
MgO	8.31	5.23
CaO	10.54	6.55
Na_2O	2.44	3.53
K_2O	none	1.90
H_2O-	0.44	0.86
H_2O+	2.04	1.96
TiO_2	1.38	2.50
ZrO_2	none	none
CO_2	none	none
P_2O_5	0.06	0.22
SO_3	none	none
S	none	none
MnO	0.26	0.42
BaO	none	0.02
SrO	none	none
Total	100.29	100.03

* Olivine diabase from Bed 108, Eagle River section, Greenstone Cliff, Keweenaw Point, Mich Sample No. 5 of Rohn's collection of Lake Superior rocks. Rock powdered to pass a 100-mesh sieve before analysis.

† "Ashbed" diabase from Bed 65, Eagle River section, Keweenaw Point, Mich. Sample No. of Rohn's collection of Lake Superior rocks. Rock powdered to pass a 100-mesh sieve before analysis, thus improving the accuracy of the figures for ferrous iron and water.

Recalculation of these analyses on the basis of the quantitative classification gives the following norms:

	1. Olivine diabase	2. Ashbed diabase
or	.....	11.12
ab	20.44	29.87
an	32.80	13.07
di	15.60	15.12
hy	15.64	15.32
ol	7.06	2.00
mt	3.48	5.57
il	2.74	4.71
ap	0.14	0.50
H_2O	2.48	2.82
Total	100.38	100.10

The olivine diabase belongs to the same class as the Birch Lake olivine gabbros, the Lighthouse Point diabase, and several others, that is, to the auvergnose type, which seems to be the dominant type of the Keweenawan, although the hessose type, which differs only in having a greater proportion of salic minerals, is also quite abundant. But the "ashbed" diabase classifies as a camptonose, very near a kilauose. It is therefore related to Irving's melaphyre of Bed 87 of the Eagle River section, and to the more basic phases of the orthoclase gabbro of Duluth.

It is to be expected that additional analyses of the Keweenawan volcanic rocks would disclose still other types, especially such as would parallel the known plutonic types. The parallelism in composition already established is quite remarkable, considering the relatively small number of analyses available. Thus, it appears that Lane's porphyrite (No. IV) and ophite (No. VII), as well as Sweet's Douglas County diabase and Wadsworth's diabase granophyrite from the Cleveland mine, are the chemical equivalents among the volcanic and dike rocks of Bayley's olivine gabbro from Pigeon Point and from T. 61 N. R. 12 W., and of A. N. Winchell's olivine gabbro and diabase from Birch Lake among the plutonic rocks. Again, Pumpelly's melaphyre from the middle of Bed 87 and Lane's porphyrite (Nos. V and VII) from Isle Royale correspond chemically with the coarse hornblende gabbro and orthoclase gabbro from Duluth. Finally, the same chemical type, viz., auvergnose, includes plutonic rocks such as Bayley's gabbro and olivine gabbro from Birch Lake, N. H. Winchell's gabbro from Bashitanaquab Lake, and A. N. Winchell's troctolite, together with volcanic or dike rocks

such as Pumpelly's melaphyre from Bed 64, Van Hise's Gogebic County diabase, and Lane's ophite from the property of the St. Mary's Land Company, and from Mt. Bohemia.

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Reviews

Triassic Ichthyosauria, with Special Reference to the American Forms. By JOHN C. MERRIAM. Memoirs of the University of California, Vol. I, No. 1, pp. 1–196, pls. 1–18, 1908.

Just forty years ago the late Professor Leidy described some fragmentary remains of ichthyosaurs from the Triassic of Nevada, the first known representatives of the order from America. About ten years later Professor Marsh made known a much more highly specialized form, *Baptanodon*, from the Jura-Cretaceous of Wyoming, a form which has been recently well described by Mr. Gilmore. Until 1895, nothing was added to our very meager knowledge of the early types from America and not much from other parts of the world. Since that time, however, Professor Merriam, the author of the present memoir, has been engaged almost continuously in the collection and study of the abundant, but often refractory remains of these animals from the Trias of the Pacific region, the final and praiseworthy results of which are embodied in the present work. In addition to the description of Leidy's *Cymbospondylus* he has founded no less than four other genera, *Torotocnemus*, *Merriamia*, *Delphinosaurus*, and *Shastosaurus*. *Mixosaurus*, *Ophthalmosaurus*, and *Ichthyosaurus* are the only other known genera of the order, hitherto unknown from America with certainty.

From the time when Scheuchser two centuries ago made known some vertebrae of an ichthyosaur from Altorf as those of a human being who had come to grief in the Noachian deluge, the gropthe ichthyosaurs have been of special interest to all classes, and much has been written about them in literature both grave and light. So perfectly were they adapted for aquatic life that it had been generally assumed, until 1887, that they were directly derived from the fishes. Baur it was, who, in the year mentioned, showed conclusively from the study of the only, and imperfectly known European Triassic form, *Mixosaurus*, that the animals must have sprung from some terrestrial crawling reptiles. A further knowledge, therefore, of the unexpectedly rich and varied ichthyosaurian fauna which has been brought to light by Dr. Merriam from the Triassic deposits of the Pacific region since 1895 when he began his energetic studies of this group, are peculiarly welcome to all interested in extinct animals and their evolution. So important are the many positive demonstrations of evolution in these forms which the

author's studies disclose, that it will be of interest briefly to summarize the more noteworthy of them. Perhaps no more familiar type of an aquatic carnivorous vertebrate can be suggested than the common gar-pike of America, a long, smooth body, short neck, propelling tail, guiding, loosely connecting fins, slender jaws, etc. The later ichthyosaurs approach such a type more closely than do or have any other air-breathing animals, in their long body, short neck, extraordinary tail-fin, paddle-like limbs, long jaws, large eyes, etc., and it is very evident that in the transition from forms not unlike a common lizard in external appearance, the animals must have passed through very great changes. In the Triassic forms chiefly those from California, Dr. Merriam has demonstrated a progressive adaptation in all these and in other characters. The locomotion of these early forms was more by aid of the limbs and less by the tail, the limbs were larger, with fewer bones, more elongated arm bones, the hind limbs were larger to supply the deficiency of a weaker tail, their connection with the trunk was stronger, the pelvis was heavier, the connection of the vertebrae with each other was more of the terrestrial kind—the vertebrae were more elongated, that is, less fish-like, etc. The skull was shorter, the jaws relatively less elongated, the teeth were more firmly fixed, the eyes were smaller, the ears less well adapted for deep diving, and the neck was less short. But it is in the tail that the most interesting progressive adaptation is seen. Every one knows how remarkable was the terminal caudal fin of the late ichthyosaurs. Dr. Merriam shows that the early forms were progressively modified from the simple flattened tail, as in the crocodile, to a tail with a preterminal dilatation like that of the mosasaurs having little or no downward bend; to the gradual turning downward of the distal end and the great expanse of the terminal, quite fish-like caudal fin. It is only in the ribs that modifications seem to have arisen not in conformity with the laws of aquatic specialization. The early forms had them attached to the centrum by a single head, while the laters ones are predominantly bicipital. However, the writer has little doubt that this primitive branch of the reptilian stem began with single-headed ribs, and that the acquisition of a double-headed attachment of a kind almost peculiarly their own, has been an independently acquired character. On the other hand, it seems very certain that a similar mode of attachment in the neck ribs of the plesiosaurs was a primitive character which has been lost in all the late forms. As the author says: "Not only is the stage of development of the Triassic representatives nearer the stem or semi-aquatic reptilian type than in the later ones, but a definite and fairly regular gradation or progressive specialization from the earliest forms to the latest seems to be recognizable in many parts of the skeleton."

But alas, notwithstanding all these conclusive evidences of evolution from a still earlier terrestrial type the Triassic forms offer no conclusive evidence of the origin of the order. The author can see no especial rhynchocephalian characters in the ichthyosaurs, so strongly urged by Baur, and he rejects the conclusions of McGregor that the ichthyosaurs are nearly related to the phytosaurs, and in both these conclusions the writer concurs. He believes that the ichthyosaurs arose from very primitive or the most primitive reptiles. Hay, recently in his extensive work on the turtles has reached the same conclusion for that order of reptiles. In other words, the results of both these authors, based upon exhaustive studies, go to support the phylogenic views expressed by Cope in his *Factors of Evolution*, published not long before his death. It seems to the writer they also destroy every shred of support remaining for the primary division of the reptilia into two chief classes, and the writer further protests against the use of the terms "Synapsida" and "Diapsida" as practically synonyms of Cope's Synaptosauria and Archosauria, proposed and sustained by him years before his death.

Briefly stated in conclusion, Dr. Merriam gives a full discussion of the geological and geographical distribution of the ichthyosaurs, their classification (he accepts Baur's two families only, the Mixosauridae and Ichthyosauridae), evolution, and structure, with especial reference to the Triassic forms, which are fully described so far as the known material has permitted. The work is well illustrated by text figures and plates.

Both the author and the University of California are to be congratulated upon the issuance of this volume, and not the least is the university to be commended for the inauguration of the handsome series of quarto memoirs of which this is the beginning; other institutions might well profit by the example.

S. W. W.

Skeletal Remains Suggesting or Attributed to Early Man in North America. By ALEŠ HADLIČKA. Bureau of American Ethnology, Bulletin No. 38, Washington, D. C., 1907.

This is a very careful, dispassionate review of the skeletal remains found at New Orleans, Quebec, Natchez, Lake Monroe (Florida) Soda, Creek, Charleston, Galaveras, Rock Bluff, Penon, Trenton, Burlington, Riverview, Lansing, Osprey, Hanson Landing, and Nebraska. The discussion of the Nebraska "loess man," which is based on personal examination of the grounds as well as study of the remains, is the climacteric point of interest, because of the low, retreating foreheads of some of the skulls. Hadlička's general conclusion (p. 98) is as follows:

The various finds of human remains in North America for which geological antiquity has been claimed have been thus briefly passed under review. It is seen that, irrespective of other considerations, in every instance where enough of the bones is preserved for comparison the somatological evidence bears witness against the geological antiquity of the remains and for their close affinity to or identity with those of the modern Indian. Under these circumstances but one conclusion is justified, which is that thus far on this continent no human bones of undisputed geological antiquity are known. This must not be regarded as equivalent to a declaration that there was no early man in this country; it means only that if early man did exist in North America, convincing proof of the fact from the standpoint of physical anthropology still remains to be produced.

Referring particularly to the Nebraska "loess man," the mind searches in vain for solid ground on which to base an estimate of more than moderate antiquity for the Gilder Mound specimens. The evidence as a whole only strengthens the above conclusion, that the existence on this continent of a man of distinctly primitive type and of exceptional geological antiquity has not as yet been proved.

There may be discouragement in these repeated failures to obtain satisfactory evidence of man's antiquity in America, but there is in this also a stimulus to renewed, patient, careful, scientifically conducted and checked exploration; and, as Professor Barbour says in one of his papers on the Nebraska find, "the end to be attained is worth the energy to be expended." A satisfactory demonstration of the presence of a geologically ancient man on this continent would form an important link in the history of the American race, and of mankind in general. The Missouri and Mississippi drainage areas offer exceptional opportunities for the discovery of this link of humanity if such really exists.

T. C. C.

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